THREE ESSAYS ON OCEAN TRANSPORTATION INDUSTRY: FROM THE FINANCIAL AND ECONOMICS PERSPECTIVES

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PhD

The Hong Kong Polytechnic University

2022

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Three Essays on Ocean Transportation Industry: From the Financial and Economics Perspectives

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A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy

March 2022

CERTIFICATE OF ORIGINALITY

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Abstract

Ocean transportation carries 80% of the global commodity trade by volume and is the indispensable transportation method over the world. This thesis investigates into the sea transportation from three closely related topics: bunker fuel market, shipping bond market and freight transportation of international trade cargo.

In the first topic, we focus on dynamic interdependence and volatility spillovers across bunker fuel markets and shipping freight markets. This study firstly explores dynamic volatility spillovers across bunker fuel markets in shipping industry. Volatilities in bunker markets are measured by using the dynamic conditional correlation GARCH model. And then bunker volatility spillovers across markets are studied. Our analysis provides evidence of unidirectional volatility spillovers within Asian (European/American) region and across regions, and also documents that Singapore bunker market is a leading market in transmitting volatility within Asian region and across regions. Furthermore, we measure time-varying volatility spillover effects among Singapore bunker market and shipping freight markets, and between Singapore bunker spot and futures market. The results reveal information transmission and could assist market participants and stakeholders to adjust hedging strategies and minimize risks according to the interrelationships across markets.

The second topic considers how shipping bond market impacts on shipbuilding market. We construct shipping credit spread as an indicator of shipping bond market. And we find that buoyant shipping credit spread in year t-2 has a negative effect on shipbuilding market in year t. Namely, it illustrates that in reality shipbuilding market would have two-year lagged reaction in response to changes in shipping bond market. Besides, it identifies whether the global financial crisis would make a difference in the effect of shipping credit spread on shipbuilding market. Furthermore, the mechanism behind our findings is that a rise of shipping credit spread increases financing costs, which reduces ship ordering and shipbuilding contracts. We document that shipping bond market is actually an identifiable channel that impacts on shipbuilding market through shipping credit spread and shipping credit supply.

The third study investigates the effects of trade agreements and exporting and importing countries on sea transportation of international trade cargo, by using a regression model on dry bulk, liquid bulk, and other cargo sector. Different from previous studies, the transportation output examined is valued in ton-miles, the product of tonnage of cargo transport and distance. The empirical results suggest that the membership of WTO (NAFTA and CAFTA) mainly has a positive (negative) effect on seaborne transportation of the exporters and importers. The estimates have also identified that China, as a major importing country, negatively affects seaborne transportation. We suppose that that it might be resulted in by operational and logistic inefficiency in sea transportation in China. An important policy implication of this study is that policy makers and market participants could recognize global economic power of major countries on international transportation and then make their own corresponding decisions and regulations in transportation areas.

Publications Arising from the Thesis

Journal Publication:

Li, X. X., and Yip, T. L. (2021). Dynamic interdependence and volatility spillovers across bunker fuel markets and shipping freight markets. Maritime Policy & Management, 1-24.

Working Papers:

Shipping Credit Spread and Shipbuilding Market. Working paper (coauthored with Dr. T. L. Yip. and Prof. N. Nomikos).

The Sea Transportation of International Trade Cargo: An Empirical Analysis. Working paper (coauthored with Dr. T. L. Yip and Prof. W. K. Talley)

Acknowledgements

Foremost, I would like to express my gratitude to Dr. Tsz Leung Yip, my Chief Supervisor. I am grateful to Dr. Yip for his supervision. His continuous guidance and support have helped me overcome many difficulties throughout my PhD study. I am thankful to have Prof. Petrus Choy as my Co-Supervisor. I am fortunate to have both of them as my supervisors.

I wish to extend my thanks to my fellow research students and friends in the department. We have had countless incredible joyful time and memory together. Life here has never been boring and tedious with them.

I would like to dedicate this thesis to my parents and brother for their unconditional love, trust, and support. I feel lucky to have such warm family.

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List of Abbreviations

BCTI: Baltic Clean Tanker Index

BDI: Baltic Dry Index

BDTI: Baltic Dirty Tanker Index

BEKK-GRACH: Multivariate GARCH Model Proposed by Engle and Kroner

CAFTA: Central American Free Trade Agreement

CCC-GARCH: Constant Conditional Correlations GARCH

CAGR: Compound Annual Growth Rate

CCF: Cross-Correlation Function

CSI :ClarkSea Index

DCC-GARCH: Dynamic Conditional Correlation GARCH

DVS: Directional Volatility Spillover Index

FE: Fixed Effect

GARCH: Generalized Autoregressive Conditional Heteroskedasticity Model

GDPPC: GDP Per Capita

GMM: Generalized Method of Moments

LSDVC: Least Squares Dummy Variable Corrected

ML: Maximum Likelihood

NAFTA: North American Free Trade Agreement

NPVS: Net Pairwise Volatility Spillover Index

NVS: Net Volatility Spillover Index

OLS: Ordinary Least Squares

SBF: Singapore bunker futures

SIN: Shipping Intelligence Network

TSI: Total Volatility Spillover Index

TVC-ECM: Time-Varying Coefficient Error Correction Model

UNCTAD: United Nations Conference on Trade and Development

VAR: Generalized Vector Autoregression

WTO: World Trade Organization

Chapter 1

Introduction

Ocean transportation plays a key role of global multimodal transport in both inbound and outbound supply chains, and it is thus important to international business studies. Seaborne transportation that is evolving to meet the requirements of carrying global goods can ensure that its international business system remains competitive and enables the comparative and competitive advantages of the system's hinterlands to be attained. The role of maritime transportation is therefore essential since maritime transportation systems and operations are important and indispensable for the effective and efficient management of flows of products in the supply chain.

In seaborne transport, bunker fuel has been increasingly used to power the vessels' engines for propulsion since the 1950s. The global bunker fuel industry had a trading value up to $109.6 billion in 2020, and it is expected to reach $164.9 billion by 2030, raising at a CAGR (a compound annual growth rate) of 4.3% from 2021 to 2030. As Notteboom and Vernimmen (2009) stated, container vessels sailing at slow speed of 20 knots from 25 knots incur a bunker cost, nearly 50% from 60% of the total ship costs. Even though at a slow steaming, bunker cost still constitutes a large proportion of operating costs. Ronen (2011) pointed out that bunker cost occupies about 75% of the operating cost of a large containership at bunker fuel price of 500 USD/ton. The more expensive the bunker price is, the higher the fuel expenses for transportation are. Therefore, as the necessary fuel consumptions of ocean transport, the cost of bunker fuel covers a major part of transport costs, directly impacting on earnings and profitability of running a ship, a shipping company, and market participants. It is essential to investigate global bunker fuel markets.

Shipping industry is categorized as capital intensive and highly geared, especially for shipbuilding market. The first shipping high-yield bond was issued in 1992, raising $125 million. In the past decades, there are an increasing number of shipping companies to have access to shipping capital market and an increasing need to raise the funds from shipping bond market. In addition, many shipping companies combine conventional bank loans with public bond issues, and have been taking the capital market as their comprehensive strategies to optimize financial structures and manage operational risks. Therefore, it is important to research into what the role of shipping bond market plays on shipbuilding market.

Ocean transportation is tightly associated with the evolution of international trade and the growth of global economy. As a pivotal transportation mode, ocean transportation carries the majority of international trade cargo. In the perspective of shipping transportation service, the economic output of this transportation mode is actually a flow of cargo moved over a distance; and the unit of the transportation output is the ton-mile, which is the product of cargo tonnage and distance travelled per time period. Since 2016, UNCTAD (the United Nations Conference on Trade and Development) of the United Nations has begun to collect the data "seaborne ton-miles of transportation service". The data for an investigation of sea transportation has not been available in the past. Thus, it provides us a possibility to develop a study on what affects sea transportation of international trade cargo in terms of the new measurement 'ton-miles'.

The overall objective of this thesis is to develop a multiple dimensional understanding of ocean transportation and shipping industry. It is achieved by researching into bunker fuel market, shipping bond market and the sea transportation of international trade cargo, as in the following three chapters. In Chapter 2, we explore time-variant interdependence and volatility spillovers across bunker fuel markets and shipping freight markets in shipping industry. Chapter 3 focuses on how shipping bond market impacts on shipbuilding market. Chapter 4 studies the sea transportation of international trade cargo in terms of the new measurement 'ton-miles'. In chapter 5, we summarize all results and findings, and provide other issues calling for future study.

Chapter 2

Dynamic Interdependence and Volatility Spillovers across Bunker Fuel Markets and Shipping Freight Markets

2.1 Introduction

Ocean transportation carries 80% of the global commodity trade by volume (UNCTAD 2009). In seaborne transportation, bunker fuel has been increasingly used to power the vessels' engines for propulsion since the 1950s. The global bunker fuel market generated $109.6 billion in 2020, and is expected to grow with a CAGR (compound annual growth rate) of 4.3%, reaching $164.9 billion by 2030. Fuel costs account for more than half of total operating costs of a liner shipping company (Yao et al. 2012). As Notteboom and Vernimmen (2009) stated, container vessels sailing at a slow speed of 20 knots from 25 knots still incur a bunker cost, nearly 50% from 60% of the total ship costs. Even though at a slow steaming, bunker cost still constitutes a large proportion of operating costs. Ronen (2011) pointed out that bunker cost occupies about 75% of the operating cost of a large containership at bunker fuel price of 500 US dollars per ton. The more expensive the bunker price is, the higher the expenses for transportation are. Therefore, as the necessary fuel consumptions of ocean transportation, the cost of bunker fuel covers a major part of transportation costs, directly impacting on earnings and profitability of running a ship, and a shipping company.

Bunker fuel is a residual fuel oil left over after refineries have processed all the more valuable fuels from the raw crude oil. It has high viscosity, requiring pre-heating and purifying before being poured into vessel engines and specific temperature for storage and pumping. The cost of transporting bunker fuel from a distant refinery is extremely high. Thus, bunker fuel is mainly stored at major ports or some refineries close to bunker ports, which forms local bunker markets. Each local bunker market has its own market condition, such as refining priorities and capacity constraints, and inherent difficulties for market participants in storing bunker fuel. In this way, local supply and demand causes pronounced price difference in different bunker ports.

However, despite heterogeneous bunker prices, bunker ports or markets do not separate from each other. Sourced from crude oil, the prices of global bunker fuel are commonly susceptible to the fluctuations of crude oil price (Shi et al. 2013; Alizadeh et al. 2004), making fluctuations in global bunker prices have a common trend. Additionally, international trade and goods transportation make bunker markets over the globe be closely connected. When there exists international trade and goods transportation between bunker ports, ships operating between two ports may need bunkering, and then that of bunker price fluctuations in either port would affect that in the other port. It means regional market participants and stakeholders are exposed to the risks of global bunker prices fluctuations, including shipowners, charterers, traders, physical bunker suppliers and financial institutions.

Certainly, there are other primary factors distinctively correlating with global bunker prices, such as freight rates and bunker futures price. Specifically, the demand for bunker fuel stems from international trade and transportation service. Bunker prices are tightly associated with transportation service price (freight rate) (Notteboom and Vernimmen 2009; Yin et al. 2017). When the demand of transportation service increases (decreases), the supply of bunker fuel remains stable but the demand of bunker fuel climbs (falls), which makes the price of bunker fuel increase (decrease) accordingly. Simultaneously, this mechanism makes bunker market participants and shipping companies exposed to the risk from the freight rate market.

Ortúzar and Willumsen (2011) stated that risk is difficult to identify and 'black swans' events are impossible to be foreseen. Stakeholders are also concerned that bunker price manifests high volatility, (Sun et al. 2019). The high price volatility means the high uncertainties and risks in bunker market and further influences on the profits of market participants. Alexandridis et al. (2018) highlighted that the corresponding derivatives could provide the opportunity to reduce the exposures of freight rate risk for shipping practitioners, holding physical freight contracts in a dramatically volatile freight market. With the evolution of bunker market, the relevant bunker fuel derivatives enable bunker market participants to hedge their positions in bunker spot market with opposite positions in bunker futures market. Alizadeh and Nomikos (2004) identified that the forward bunker market could efficiently hedge against price fluctuations in bunker spot markets. However, Tao and Green (2012) hypothesized that the volatility spillover could explain the information flow between spot and futures market, and a news shock in either market would increase volatility and volatility-persistence in both markets. Thus, it is interesting to identify the intensity of interdependence between the bunker spot and futures market in terms of volatility spillovers.

The aforementioned reasons highlight the importance of modelling the cross-markets interdependencies and information spillovers among bunker markets and the relevant markets. However, the extant literatures keep silent about the dynamic relationship across bunker spot markets (hereinafter bunker markets), shipping freight markets, and bunker futures market. The aim of this chapter is to provide new evidence of cross-market spillover effects of bunker market by examining the existence, direction and magnitude of dynamic volatility spillovers among bunker markets, between bunker spot and freight rate markets, and between bunker spot and futures market.

The research contributes to the existing literature in the following ways. First, it captures the dynamic conditional correlations across global bunker markets, between bunker and shipping freight markets, and between bunker spot and futures markets, by exploiting DCC-GARCH model. Second, it tests the existence, the magnitude and the direction of dynamic volatility spillovers across global bunker markets, among bunker and freight markets and between bunker spot and futures markets, by using the econometric methods developed by Diebold and Yilmaz (2009, 2012). In this way, the total, directional, net and net pairwise spillovers are derived over time across those markets. To the best of our knowledge, it is not considered in the earlier work on volatility spillovers across bunker spot markets, combining freight markets and bunker futures markets. Although Sun et al. (2019) examined the volatility spillovers of tanker freight market and bunker market, they only concentrated on derivatives market, and did not consider information spillovers across bunker physical and derivatives markets, as well as of the industry-wide freight markets. This study, from a comprehensive perspective, presents the volatility transmission mechanism more accurately. And gaining a knowledge of the overall volatility transmission can be helpful for market participants to develop risk management strategies. Third, this study finds that the volatility spillovers in bunker markets are sensitive to time-specific events such as the global financial crisis and COVID-19 pandemic.

The empirical findings of this study can be summarized as follows. First, an absolute volatility transmitter to other markets is found in each region and across regions, by examining static and dynamic volatility spillovers among bunker markets in Asian, European, American region and across regions. Specifically, Singapore, Rotterdam and Houston are the net transmitters of spillovers to other markets in Asian, European and American region, respectively. And further, Singapore is still a leading market in the three markets, Singapore, Rotterdam and Houston. Thus, all bunker traders, shipping carriers and participants in global bunker markets need to pay more attention to the situation in Singapore market. Also, the volatility spillover effects are of great significance for stakeholders and investors in bunker markets to manage risk exposures. When there is a possible and localized shock to bunker price in the Singapore market, such as strikes, terrorism (military conflict), or bad weather, bunker prices of other bunker markets would be affected. The time-varying cross-market interdependences increase aggregate risk exposures. Those risk exposures could be incorporated into bunker derivatives pricing model to improve hedging performance. Second, shocks to Singapore bunker market significantly contributes to the forecast error variance of shipping freight markets, and the magnitude varies over the sub-segments of shipping freight markets. The volatility transmission from Singapore bunker market to shipping clean tanker market is higher than that to others. Third, it provides the evidence of volatility spillovers mainly from bunker spot to futures market in Singapore. This result is in opposition with the relevant financial literature (Antonakakis, Floros, and Kizys, 2016), suggesting that Singapore futures market is inferior in hedging risks than other financial derivatives markets. In other word, it illustrates that bunker spot and futures markets cannot adjust similarly in response to the same market-wide news, and bunker futures market is not equally informative as bunker spot markets.

The rest of the chapter is organized as follows. Section 2 displays the literature review. Section 3 describes the related data. Section 4 outlines the econometric methodology used. Section 5 presents the results and discusses findings. Section 6 concludes this research.

2.2 Literature Review

The interest about this specific asset class, bunker, has been pronounced due to the dramatically larger price volatility after the 2000s (Alizadeh et al. 2004; Stefanakos and Schinas 2014). Market participants, such as shipowners and bunker suppliers, are exposed to the global time-varying fluctuation of bunker prices, which directly impacts on costs and earnings of their enterprises. For cost-controlling and risk-hedging, it is crucial for market participants to have a deep understanding of the information transmission of bunker markets, namely the sensitivity of bunker markets to fluctuations of volatility in other bunker markets induced by exogenous shocks. For instance, in a fixture settled for shipping between Singapore and Hong Kong, the change of bunker price in the one market would make fluctuations of bunker price in the other one, hence affecting costs and earnings of this fixture. Thus, one part of this research focuses on the information transmission between different bunker markets.

Responding to the increasing interests in cross-markets co-movement, a large number of studies have examined the information transmission across different markets. It is well known from existing literatures that the factors highly correlated with the fluctuation of bunker prices include shipping freight rates and bunker futures prices. Notteboom and Vernimmen (2009) argued that dramatic variations in bunker price have made a significant effect on freight rates during the past decades. Alizadeh et al. (2004) investigated the efficiency of forward bunker market. Many efforts have been made to capture the relationship between crude oil futures, bunker futures, and freight rates (spot and forward) in shipping industry (Sun et al. 2018; Sun et al. 2019). But there is relatively limited research on how the information transmits between a leading bunker market and freight markets, and between a leading bunker spot market and its corresponding futures market. Therefore, it is also of utmost importance for stakeholders to manage their exposed risks, by quantifying information transmission across bunker spot and freight markets, and between bunker spot and futures market.

The issue of information transmission across markets is widely investigated by numerous studies. Specifically, they focus on how information from one market is transmitted to another market. Empirical research of information transmission is studied by price discovery and volatility spillovers. Price discovery is frequently employed to examine information transmission between futures markets (Chan 1992; Ghosh 1993), while volatility spillover is used to discuss information transmission across various markets.

Most studies have employed GARCH-family models to explore the asymmetries of market volatility. Drobetz et al. (2012) explored whether incorporating macroeconomic factors or asymmetric effects into a GARCH model could better explain the volatility in shipping freight markets. Namely, by comparing the three specifications, GARCH-X, EGARCH and EGARCH-X, they confirmed that both macroeconomic forces and asymmetric effects have a significant influence on the volatility in the tanker freight market and could be incorporated into conditional variance equations. Then, they studied volatility spillovers between spot and futures markets by the Cross-Correlation Function (CCF) proposed by Cheung and Ng (1996) for testing causality-in-variance between two markets. They found the existence of significant volatility asymmetries in both the FTSE100 spot index and index futures prices: negative shocks of volatility have a significantly larger effect on the conditional variance in each market than positive shocks do. Their CCF tests suggested that variance shocks in each market are impounded more-or-less simultaneously in both markets. And the CCC-GARCH model (Bollerslev 1990) exhibits the constant conditional correlations and the BEKK-GRACH model (Engle and Kroner 1995) is difficult to make an unbiased estimation of parameters of the conditional volatility under high dimensions. However, the dynamic conditional correlation GARCH (DCC-GARCH) model allows for heteroscedasticity of conditional volatility and changes in conditional correlations over time (Caporin and McAleer 2012). Therefore, this study adopts the DCC-GARCH model introduced by Engle (2002), to capture the dynamic conditional variance and generate volatility series in bunker markets and bunker-related markets for further exploring volatility spillovers in this research.

Tao and Green (2012) hypothesized that there exists the volatility spillovers if news shocks to any one market will enlarge volatility in all markets. Thus, the key to exploring volatility spillovers is investigating how shocks in one market lead to the fluctuations of volatility in other markets. Existent studies on the issue of volatility spillovers build on forecast-error variance decompositions in a generalized vector autoregressive framework, which are varying to the ordering of the variables. This chapter introduces volatility spillover index of Diebold and Yilmaz (2009, 2012) as is unchanged with the ordering of variables, to examine volatility spillovers among bunker markets and bunker-related markets. The spillover index approach could measure the contributions of shocks to a variable to the forecast error variances of all variables in a VAR model. It makes the directions of volatility spillovers accessible by decomposing total volatility spillovers, and meanwhile identifies the transmitters and recipients of volatility. Moreover, the dynamics of volatility spillovers plots could be obtained by using rolling-window estimation. Ko (2018) adopted a time-varying coefficient error correction model (TVC-ECM) to uncover hidden dynamic patterns in shipping freight markets. Therefore, the dynamics in this study make the evolution of spillover effects across markets traced over time, and overcomes the limitations of static volatility spillovers which masks potential information over time.

Further, Antonakakis et al. (2016) used the spillover index to explore the dynamic spillovers (interdependences) between stock spot and futures markets volatilities. Tsouknidis (2016) captured the dynamic volatility spillovers across shipping freight markets. Dynamic spillover effects across petroleum spot and futures volatilities, trading volume and open interest are explored by Magkonis and Tsouknidis (2017). In contrast to existing research on this issue, this study explores for the first time the dynamic volatility spillovers across bunker spot markets globally and attempt to find a leading port in terms of volatility spillovers. And then, this study focuses on evaluating how the leading market carries information for the volatility variations of freight market and its futures market, which has not been addressed by relevant literature.

2.3 Empirical Model and Methodology

The volatility spillovers across bunker markets and bunker-related markets are studied by using a two-step approach. In the first step, the time series of volatilities is specified by the DCC-GARCH (dynamic conditional correlation GARCH) model proposed by Engle (2002), and meanwhile the correlations between markets are measured. Secondly, in order to investigate volatility spillovers across markets, the spillover indices are derived from a variance decomposition based on 10-step-ahead forecasts. According to this approach, we examine dynamic volatility spillovers among bunker markets in Asian, European, American regions (shown in section 2.5.1 and 2.5.2), across bunker spot market and freight markets (displayed in section 2.5.3), and between bunker spot and future markets (presented in section 2.5.4).

Firstly, the DCC-GARCH model is utilized to obtain volatility series and capture the correlation and co-movements across bunker and bunker-related markets, and is defined as

$$r_t = \mu + \varepsilon_t, \tag{2-1}$$

where r_t is a vector of price returns, μ is a constant term, and ε_t is a vector of error terms.
The univariate GARCH model is written as,

$$h_{ii,t}^2 = c_i + \theta_{1i}\varepsilon_{ii,t-1}^2 + \theta_{2i}h_{ii,t-1}^2, \tag{2-2}$$

from which conditional variances are estimated, $c_i \geq 0,\ \theta_{1i} \geq 0,\ \theta_{2i} \geq 0\ for\ i = 1 \dots N$. And H_t is the conditional variance-covariance matrix,

$$H_t = M_t R_t M_t, \tag{2-3}$$

where M_t is the diagonal matrix of squared root conditional variances, $M_t = diag(h_{ii,t}^{\frac{1}{2}}, \dots, h_{NN,t}^{\frac{1}{2}})'$, and $R_t = [\rho_{ij,t}]$ is the conditional correlation matrix,

$$R_t = diag(s_{ii,t}^{-\frac{1}{2}}, \dots, s_{NN,t}^{-\frac{1}{2}}) S_t diag(s_{jj,t}^{-\frac{1}{2}}, \dots, s_{NN,t}^{-\frac{1}{2}}), \text{ or} \tag{2-4}$$

$$\rho_{ij,t} = \frac{s_{ij,t}}{\sqrt{s_{ii,t}s_{jj,t}}} \tag{2-5}$$

where $S_t = [s_{ij,t}]$ is a symmetric positive definite matrix, expressed as

$$S_t = [s_{ij,t}] = (1 - \alpha - \beta)\bar{S} + \alpha u_t u_{t-1}' + \beta S_{t-1}, \tag{2-6}$$

where $u_t = (u_{1t}, \dots, u_{Nt})'$ is a vector of standardized residuals from the univariate GARCH estimation step, $\bar{S}$ is the N×N unconditional variance matrix of u_t, and $\alpha\ and\ \beta$ are nonnegtive parameters satisfying $\alpha + \beta < 1$. In this study, the DCC-GARCH (1,1) model is estimated for all cases and the conditional variances are derived for studying volatility spillovers in the following section.

Second, the VAR (generalized Vector Autoregression) model of KPPS (Koop, Pesaran, and Potter 1996; Pesaran and Shin 1998) is adopted to produce variance decompositions, which are invariant to the ordering of variables. Put differently, the spillover index, proposed by Diebold and Yilmaz (2009, 2012), is calculated by using the forecast error variance decomposition method of the VAR model, representing how a volatility shock from one market spread to other markets. The spillover index in this study indicates how much volatility transmits across bunker markets and bunker-related markets.

The framework of the generalized VAR is given by,

$$\boldsymbol{V_t} = \sum_{i=1}^{n} \boldsymbol{\beta_i V_{t-i}} + \boldsymbol{\varepsilon_t}\ , \tag{2-7}$$

where $V_t = (V_{1,t}, V_{2,t}, \ldots V_{M,t})$ is a vector of M endogenous variables, $\beta_i, i = 1, \ldots, n$, are $M \times M$ parameter matrices and $\boldsymbol{\varepsilon_t} \sim (\boldsymbol{0}, \Sigma)$ is a vector of disturbances that have an independent distribution over time; $t = 1, \ldots, T$ is denoted as the time; $i = 1, \ldots, n$ is the lag order. The moving average representation is,

$$\boldsymbol{V_t} = \sum_{j=0}^{\infty} \boldsymbol{P_j \varepsilon_{t-j}}\ , \tag{2-8}$$

where $\boldsymbol{P_j}$ is $M \times M$ parameter matrices, and $P_j = \beta_1 P_{j-1} + \beta_2 P_{j-2} \ldots + \beta_n P_{j-n}$.

A variance decomposition is a tool to decompose the forecast error variances of each variable into parts attributed to various shocks (Diebod and Yilmaz 2015, Chap. 1). According to Diebold and Yilmaz (2012), the ij entry of the H-step-ahead forecast error variance decomposition is $\theta_{ij}(H)$,

$$\theta_{ij}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' P_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i' P_h \Sigma P_h' e_i)} \tag{2-9}$$

Σ is the (estimated) variance matrix of the error vector $\boldsymbol{\varepsilon}$, σ_{jj} the (estimated) standard deviation of the error term for the j-th equation and e_i a selection vector with one as the i-th element and zeros otherwise. It is notable that orthogonal innovations are necessary in order to conduct variance decomposition analysis. When using Cholesky factorization to identify, the orthogonality could be achieved but the variance decomposition is related to the orderings of the variables in the model. By contrast, the VAR model of KPSS could address the problem and do not orthogonalize shocks. It allows the correlated shocks and employs the observed distributions of errors to consider the correlated shocks. Since the shocks to each variable are not orthogonalized, the sum of contributions to the forecast error variance is not always equal to one. In other words, the sum of raw elements in the variance decomposition table is not always equal to one.

The spillover index is an $M \times M$ matrix $\theta(H) = [\theta_{ij}(H)]_{i,j=1,\ldots,M}$, in which the main diagonal elements represent the own contributions of shocks to the j-th market to its own forecast error variance; and the off-diagonal elements show the cross contributions of shocks to the j-th market to the forecast error variance of i-th market ($i \neq j$), which means that the off-diagonal ones could be employed to illustrate possible spillovers.

Each element in $M \times M$ matrix $\theta(H) = [\theta_{ij}(H)]_{i,j=1,\dots,M}$, is normalized by the row sum, as follows,

$$\tilde{\theta}_{ij}(H) = \frac{\theta_{ij}(H)}{\sum_{j=1}^{M} \theta_{ij}(H)}, \quad (2\text{-}10)$$

then, $\sum_{j=1}^{M} \tilde{\theta}_{ij}(H) = 1$, $\sum_{i,j=1}^{M} \tilde{\theta}_{ij}(H) = M$.

The total volatility spillover index (TSI) is estimated as:

$$TSI(H) = \frac{\sum_{i,j=1;i\neq j}^{M} \tilde{\theta}_{ij}(H)}{\sum_{i,j=1}^{M} \tilde{\theta}_{ij}(H)} \quad (2\text{-}11)$$

The directional volatility spillover index ($DVS_{i,FROM}$) received by the $i\text{-}th$ market from all other j_{th} markets is estimated as:

$$DVS_{i,FROM}(H) = \frac{\sum_{j=1;i\neq j}^{M} \tilde{\theta}_{ij}(H)}{\sum_{i,j=1}^{M} \tilde{\theta}_{ij}(H)} \quad (2\text{-}12)$$

The directional volatility spillover index ($DVS_{i,TO}$) transmitted from the $i\text{-}th$ market to all other $j\text{-}th$ markets is estimated as:

$$DVS_{i,TO}(H) = \frac{\sum_{j=1;i\neq j}^{M} \tilde{\theta}_{ji}(H)}{\sum_{i,j=1}^{M} \tilde{\theta}_{ij}(H)} \quad (2\text{-}13)$$

Net volatility spillover index (NVS) from and to the $i\text{-}th$ market is estimated as:

$$NVS_i = DVS_{i,TO}(H) - DVS_{i,FROM}(H) \quad (2\text{-}14)$$

which gives the difference of a transmitter of volatility shocks from a net receiver of volatility shocks. When the value of NVS is positive, the $i\text{-}th$ market is a net transmitter of volatility shocks, and otherwise the $i\text{-}th$ market is a net receiver of volatility shocks.

The net pairwise volatility spillover index (NPVS) denotes the interdependence of pairwise markets:

$$NPVS_{ij}(H) = \frac{\tilde{\theta}_{ij}(H)}{\sum_{i,j=1}^{M} \tilde{\theta}_{ij}(H)} - \frac{\tilde{\theta}_{ji}(H)}{\sum_{i,j=1}^{M} \tilde{\theta}_{ij}(H)} \quad (2\text{-}15)$$

which gives the information that a market is a net transmitter or receiver of volatility when only considering paired markets. The value of NPVS is positive, it means that the $i\text{-}th$ market is a net volatility transmitter compared to the $j\text{-}th$ market, and otherwise the $i\text{-}th$ market is a net volatility receiver. This study examines static and dynamic volatility spillovers among bunker markets, across bunker and freight markets, and between bunker spot and futures markets.

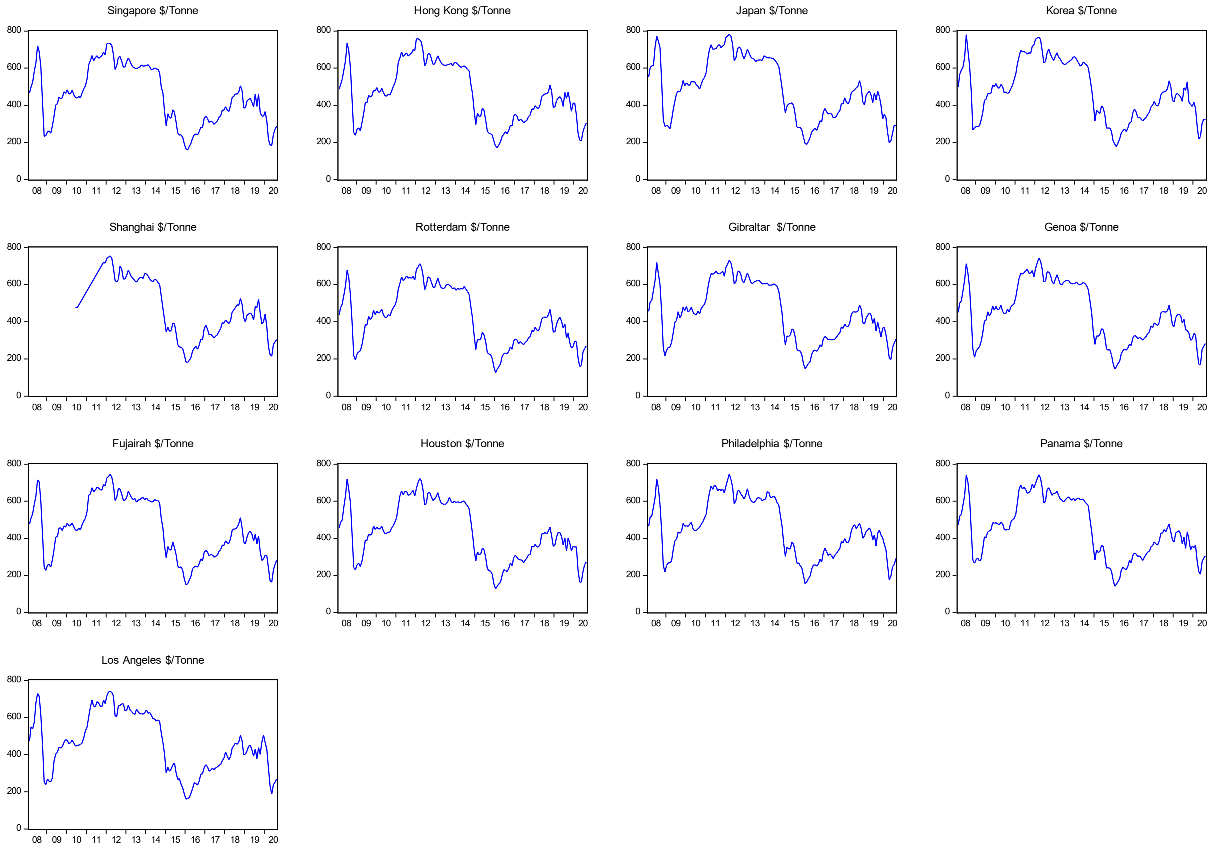
2.4 Data

Our data set consists of monthly prices for bunker fuel in 13 ports, for four shipping freight rate indices and for one bunker futures. Our monthly data is easier to identify changes in trends, and to model cyclical variability especially during the long period over 20 years. Conversely, changes on a more frequent basis, such as weekly or daily, are not easily integrated into a long-term analysis. The common bunker fuel, IFO 380, is the widely used in shipping industry. Corbett and Winebrake (2008) pointed out that IFO380 sold worldwide occupied about 75% of the world volume of all bunker fuels. Approximately 70% of bunker fuel sales in Singapore is IFO 380 (Notteboom and Vernimmen 2009). Although bunker fuel is traded at different prices in different ports over the world, the majority of trading volume of bunker fuel is centred on several busy ports. Busy bunkering ports are those along major trading routes and around choke points, for instance, the port of Singapore and Fujairah. Thus, this study collects the data of bunker prices from 13 bunker ports, namely Singapore, Hong Kong, Japan, Korea, Shanghai, Rotterdam, Gibraltar, Genoa, Fujairah, Houston, Philadelphia, Panama, and Los Angeles. Referring to their geographical locations, those bunker ports are grouped into three regions, Asia, Europe and America. Singapore, Hong Kong, Japan, Korea and Shanghai port belong to Asian region. The port of Rotterdam, Gibraltar, Genoa and Fujairah port are included into European region. American region involves Houston, Philadelphia, Panama and Los Angeles port.

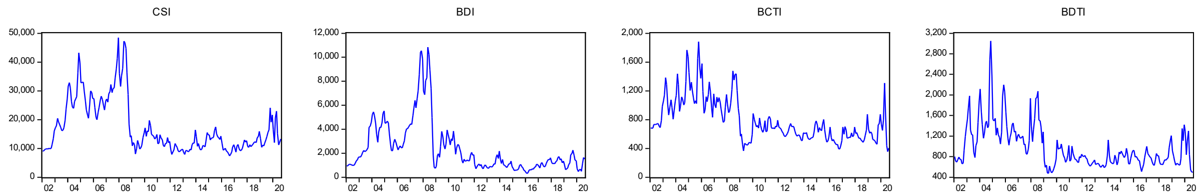
Regarding shipping freight markets, four freight rate indices are examined, CSI, BDI, BCTI, and BDTI. ClarkSea Index (CSI) reflects the freight rate level for the entire shipping industry; Baltic Dry Index (BDI) is the overall freight rate for dry-bulk shipping; Baltic Clean Tanker Index (BCTI) and Baltic Dirty Tanker Index (BDTI) represents the overall freight rate for major liquid-bulk shipping. And then, the Singapore IFO 380, 1-month futures contract is chosen, which is relatively active in bunker futures markets. Due to the limited access, the data of bunker prices for Asian ports runs from January 2002 to August 2020, for European ports from February 2008 to August 2020, for American ports from December 1991 to August 2020; the data of four freight rate indices covers the period from January 2002 to August 2020; the data of Singapore IFO 380 1-month bunker futures, hereinafter Singapore bunker futures (SBF), spans the period from November 2005 to August 2020. All data employed in this study can be accessed by Clarksons Shipping Intelligence Network (SIN) and Bloomberg.

Figure 2-1 plots time path of bunker prices in 13 ports (Panel A), of index values for shipping freight rates (Panel B), and of Singapore bunker futures (Panel C). All series exhibit significant variation over time. Table 2-1 presents the descriptive statistics of monthly bunker prices in 13 bunker ports (Panel A) and monthly index values for all four shipping freight rate indices examined (Panel B), as well as the monthly prices of Singapore bunker futures (Panel C). As shown, the range of the average bunker prices in 13 ports is from \$400/tonne to \$470/tonne. Rotterdam with \$403.28/Tonne has the lowest in the mean bunker prices, and the highest bunker price, \$469.13/Tonne, is in Japan. All of bunker prices in 13 ports fluctuate above \$125/Tonne and below \$785/Tonne. Table 2-1 displays the descriptive statistics of all our original data. Thus, it is not surprising that our original data are not normal distributed with regard to Jarque-Bera tests. But we use the transformed data by logarithm in our later regression analyses, making our data match the normal distributions.

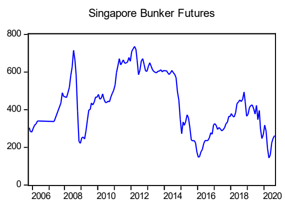
Panel A



Panel B



Panel C



Note: CSI denotes ClarkSea Index; BDI denotes Baltic Dry Index; BCTI denotes Baltic Clean Tanker Index; BDTI denotes Baltic Dirty Tanker Index. For the easier view, we only display the price plots of all bunker ports during the period from 2008 to 2020.

Figure 2-1. Monthly path of bunker prices in 13 ports, indices of shipping freight rates, and Singapore bunker futures.

Table 2-1 Descriptive statistics of all variables in a monthly frequency

Panel A Bunker Prices

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Observations
Singapore	431.54	392.13	733.30	159.63	161.17	0.21	1.80	7.05	105
Hong Kong	444.37	411.95	758.75	172.38	161.70	0.23	1.84	6.84	105
Japan	469.13	429.70	781.00	189.63	167.34	0.20	1.80	7.03	105
Korea	462.39	420.25	765.90	176.25	161.19	0.20	1.83	6.68	105
Shanghai	457.64	435.75	755.40	181.25	160.75	0.17	1.80	6.80	105
Rotterdam	403.28	355.75	712.60	125.90	161.04	0.26	1.75	8.04	105
Gibraltar	429.64	390.13	732.30	148.00	161.00	0.22	1.76	7.66	105
Genoa	428.06	387.63	742.20	145.50	162.71	0.23	1.77	7.48	105
Fujairah	428.13	386.00	745.20	149.50	164.93	0.24	1.79	7.46	105
Houston	411.62	366.88	722.10	126.00	162.82	0.21	1.78	7.23	105
Philadelphia	436.19	412.94	745.90	154.80	158.43	0.17	1.79	6.94	105
Panama	428.66	385.50	742.00	140.80	162.85	0.25	1.79	7.59	105
Los Angeles	443.27	423.60	740.50	160.70	163.26	0.16	1.81	6.64	105

Panel B Freight indices

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Observations
CSI	17236.16	13680.69	48493.56	7364.09	9041.39	1.34	4.14	79.55	224
BDI	2372.83	1504.17	10843.65	306.90	2121.18	1.95	6.83	278.44	224
BCTI	790.94	699.63	1882.68	355.83	295.92	1.15	3.97	58.06	224
BDTI	985.09	826.99	3050.00	477.84	414.56	1.73	6.85	249.96	224

Panel C Bunker futures

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Observations
Singapore Bunker Futures	432.10	428.52	735.94	143.24	155.05	0.14	1.88	9.08	164

Notes: CSI denotes ClarkSea Index; BDI denotes Baltic Dry Index; BCTI denotes Baltic Clean Tanker Index; BDTI denotes Baltic Dirty Tanker Index. The units of all bunker prices are U.S. dollars per ton per month; the units of all freight rate indices are U.S. dollars per month; the unit of Singapore Bunker Futures is U.S. dollars per ton.

2.5. Empirical Findings

2.5.1. Volatility spillovers across bunker markets

Table 2-2a reports the empirical results of the AR(1)-DCC-GARCH model, for the bunker markets in Asian region, European region and American region. The estimated dynamic conditional correlation parameters $\rho_{ij,t}$ are statistically significant for bunker markets in Asian, European and American region cases. As shown, it exhibits high co-movements for all bunker markets in Asian, European and American region since all correlations between markets are bigger than 0.6. The largest significant dynamic conditional correlations are 0.938083 between Singapore and Hong Kong in Asian region, 0.913368 between Rotterdam and Genoa in European region, and 0.846038 between Houston and Panama in American region. The correlation between Singapore (Rotterdam / Houston) and several ports in Asian (European / American) region is relatively higher. The economic rationales behind those findings are that Singapore, Rotterdam and Houston port are currently the three largest ports regarding trade volume of bunker fuel in the world.

Table 2-2a Estimation results of the AR(2)-DCC-GARCH model for the bunker markets in Asian, European and American regions

	Asia market				
	Singapore	HK	Japan	Korea	Shanghai
Panel A: 1-Step, univariate GARCH estimates and univariate diagnostic tests					
constant	73.4691**	206.3742***	74.0286***	66.0316**	47.6151*
	[2.19]	[4.11]	[2.99]	[2.07]	[1.91]
θ1	0.7598***	0.5951***	0.3356***	0.4029***	0.4603**
	[4.97]	[3.71]	[3.44]	[3.34]	[2.02]
θ2	0.3495***	0.2360**	0.6356***	0.5858***	0.5724***
	[4.52]	[2.13]	[9.78]	[5.85]	[3.73]
Q(30)	33.7470	42.3190	24.8230	45.9350	34.3320
	[0.53]	[0.18]	[0.90]	[0.10]	[0.50]
Q^2(30)	27.1200	36.6600	44.3060	37.2490	26.8050
	[0.86]	[0.44]	[0.16]	[0.41]	[0.87]

Panel B: 2-Step, correlation estimates and multivariate diagnostic tests	
ρ Singapore-HK	0.9381(869.41)***
ρ Singapore-Japan	0.7796(232.14)***
ρ Singapore-Korea	0.8474(371.24)***
ρ Singapore-Shanghai	0.6459(41.06)***
ρ HK-Japan	0.7952(239.12)***
ρ HK-Korea	0.8562(393.95)***
ρ HK-Shanghai	0.6729(41.83)***
ρ Japan-Korea	0.7937(262.32)***
ρ Japan-Shanghai	0.6434(40.35)***

ρ Korea-Shanghai	0.6325(39.75)***
α	0.1050(3.68)***
β	0.5466(4.19)***
log-likelihood	-3656.4630
SC	33.2268
HQC	33.0088
AIC	32.8613
Observations	224
Period	2002M01 to 2020M08

Table 2-2a (continued)

	Europe market			
	Rotterdam	Gibraltar	Genoa	Fujairah
Panel A: 1-Step, univariate GARCH estimates and univariate diagnostic tests				
constant	17.2484**	146.0533**	17.6230**	40.1727***
	[2.48]	[2.48]	[2.43]	[4.16]
θ1	0.3834***	0.7137***	0.4297***	0.5414***
	[5.03]	[3.13]	[5.67]	[6.56]
θ2	0.6424***	0.2793**	0.6144***	0.4980***
	[10.89]	[2.02]	[11.37]	[10.06]
Q(30)	29.7840	29.1050	27.5650	40.3830
	[0.72]	[0.75]	[0.81]	[0.25]
Q^2(30)	25.1750	15.6100	19.1060	19.9580
	[0.91]	[1.00]	[0.99]	[0.99]
Panel B: 2-Step, correlation estimates and multivariate diagnostic tests				
ρ Rotterdam-Gibraltar	0.8985 (201.18)***			
ρ Rotterdam-Genoa	0.9135 (139.16)***			
ρ Rotterdam-Fujairah	0.8961 (98.67)***			
ρ Gibraltar-Genoa	0.9109 (135.15)***			
ρ Gibraltar-Fujairah	0.8437 (127.31)***			
ρ Genoa-Fujairah	0.8663 (121.47)***			
α	0.1787 (7.15)***			
β	0.6877 (14.72)***			
log-likelihood	-3943.0770			
SC	23.1464			
HQC	23.0324			
AIC	22.9570			
Observations	151			
Period	2008m02 to 2020m08			

Table 2-2a (continued)

	America market			
	Houston	Panama	Philadelphia	Los Angeles
Panel A: 1-Step, univariate GARCH estimates and univariate diagnostic tests				
constant	13.0556**	14.6028**	6.9702*	3.9361
	[2.27]	[2.57]	[1.91]	[1.23]

θ1	0.3472***	0.3389***	0.2183***	0.1732***
	[5.54]	[5.35]	[4.98]	[5.44]
θ2	0.7073***	0.7043***	0.8023***	0.8499***
	[16.94]	[16.65]	[29.16]	[45.20]
Q(30)	20.7160	33.3140	29.2700	23.4250
	[0.97]	[0.55]	[0.74]	[0.93]
Q^2(30)	19.2000	13.1390	25.0090	26.8520
	[0.99]	[1.00]	[0.92]	[0.87]
Panel B: 2-Step, correlation estimates and multivariate diagnostic tests				
ρ Houston-Panama	0.8460 (246.89)***			
ρ Houston-Philadelphia	0.8186 (196.43)***			
ρ Houston-Los Angeles	0.7289 (172.46)***			
ρ Panama-Philadelphia	0.8094 (211.07)***			
ρ Panama-Los Angeles	0.7022 (182.68)***			
ρ Philadelphia-Los Angeles	0.7110 (140.03)***			
α	0.0799 (5.81)***			
β	0.8317 (23.28)***			
log-likelihood	-5453.9030			
SC	32.0233			
HQC	31.8624			
AIC	31.7560			
Observations	345			
Period	1991M12 to 2020M08			

Notes: $Q(30)$ *and* $Q^2(30)$ are the Ljung and Box statistics for testing serial correlation with the null hypothesis of no serial correlation in the univariate standardized and squared standardized residuals with 30 lags. * 10% significant. ** 5% significant. *** 1% significant.

With the estimated AR(1)-DCC-GARCH model in all cases, the resulting variances series are derived to reflect volatility over time. And volatility spillover indices are obtained by using the vector autoregression of order 1 and the generalized variance decompositions of 10-step-ahead forecast errors. Table 2-2b presents the static total, directional and net volatility spillovers for bunker markets within Asian, European and American regions, respectively. The ij-th entry indicates the estimated contribution to the forecast error variance i sourcing from innovation of market j. 'Contribution To others' is the off-diagonal column sum. 'Contribution From others' is the raw sum, excluding the main diagonal element. Net volatility spillovers are obtained by deducting 'Contribution From others' from 'Contribution To others'. And the ratio of the off-diagonal elements to all the elements including diagonal elements corresponds to the total spillover index (TSI).

Table 2-2b Volatility spillovers across bunker markets in Asian, European and American regions

Asian region	From (j)					
To (i)	Singapore	Hong Kong	Japan	Korea	Shanghai	Contribution From others
Singapore	88.7	4.7	2.3	3.7	0.6	11.3
Hong Kong	70.6	28.8	0.2	0.3	0.1	71.2
Japan	54.5	25.1	15.5	0.2	4.7	84.5
Korea	75.4	6.1	4.3	12.9	1.3	87.1
Shanghai	33.7	10.4	11.3	3.4	41.2	58.8
Contribution TO others	234.3	46.3	18.0	7.6	6.7	312.9
Contribution incl. own	323.0	75.1	33.5	20.5	47.9	
Net volatility spillovers	223.0	-24.9	-66.5	-79.5	-52.1	TSI=62.6%

Table 2-2b (continued)

European region	From (j)				
To (i)	Rotterdam	Gibraltar	Genoa	Fujairah	Contribution From others
Rotterdam	74.5	0.3	2.8	22.4	25.5
Gibraltar	66.5	9.8	0.9	22.7	90.2
Genoa	66.3	0.3	10.1	23.3	89.9
Fujairah	70.4	0.5	0.5	28.6	71.4
Contribution TO others	203.3	1.1	4.2	68.4	277.0
Contribution incl. own	277.8	11.0	14.3	97.0	
Net volatility spillovers	177.8	-89.7	-85.7	-3.0	TSI=69.3%

Table 2-2b (continued)

American region	From (j)				
To (i)	Houston	Panama	Philadelphia	Los Angeles	Contribution From others
Houston	68.9	25.9	4.2	1.0	31.1
Panama	59.2	36.8	3.6	0.3	63.2
Philadelphia	67.0	27.9	4.8	0.3	95.2
Los Angeles	62.1	27.1	3.5	7.2	92.8
Contribution TO others	188.4	80.9	11.4	1.6	282.3
Contribution incl. own	257.3	117.7	16.2	8.8	
Net volatility spillovers	157.3	17.7	-83.8	-91.2	TSI=70.6%

Table 2-2b indicates that the volatility of Singapore (Rotterdam/Houston) market spills over to the volatility of other markets in Asia (Europe/America) region. Specifically, in Asian region, Singapore market volatility is responsible for 70.6% (54.5%/75.4%/ 33.7%) of the forecast error variance of Hong Kong (Japan/Korea/Shanghai) market volatility, while Hong Kong (Japan/Korea/Shanghai) market volatility is only responsible for 4.7% (2.3%/3.7%/0.6%) of the forecast error variance of Singapore market volatility; in European region, Rotterdam market explains of 66.5% (66.3%/70.4%) of the forecast error variance of Gibraltar (Genoa/Fujairah) market volatility, while receiving the volatility from Gibraltar (Genoa/Fujairah) market is only 0.3% (2.8%/22.4%); in American region, Houston market contributes 59.2% (67%/62.1%) to the forecast error variance of Panama (Philadelphia/Los Angeles) market volatility, but ultimately receives 31.1% of the forecast error variance of Panama, Philadelphia and Los Angeles market. Singapore, Rotterdam and Houston market play a leading role in transmitting volatility in Asian, European and American region, respectively. This finding is also supported by the dramatic positive value of net volatility spillovers of Singapore, Rotterdam and Houston market. It suggests that market participants in Asia (Europe/America) region should closely monitor the situation in Singapore (Rotterdam/Houston) market.

Furthermore, static analysis might cover up the changes of volatility spillovers occurred over time, and conceal efficient information in volatility spillovers during the sample period. Hereby, the 50-week rolling windows are used to estimate and obtain time-varying volatility spillover indices. Figure 2-2, 2-3 and 2-4 plots the dynamic spillover indices, which offer a time-varying insight into volatility interdependence among bunker markets in Asian, European and American region, respectively. The time-varying total, directional and net volatility spillover indices are reported in the three figures. The total spillover index (TSI) of bunker markets in Asia (Europe/America) region changes between the range of 64% (56%/20%) and 76% (74%/76%). Directional volatility spillovers demonstrates the time-variant features in all three regions. In Asian region (Figure 2-2), the values of the directional volatility spillovers from Singapore market to the other markets are above 200 during the nearly whole sample period. The values of directional volatility spillovers from Rotterdam market to other markets in European region (Figure 2-3) vary from 80 to 290. In American region (Figure 2-4), the values of directional volatility spillovers, from Houston market to other markets, fluctuate between 50 and 250 during the most of periods. Net volatility spillovers of each market experience a noticeable variation over time in three regions. Those variations might be caused by time-specific events, such as the oil price plunge beginning from the mid of 2014. In Asian region (Figure 2-2), net volatility spillovers of Singapore market retain positive values throughout the sample period, while net spillovers of Hong Kong, Japan, Korea and Shanghai market are negative during the most of periods. In European region (Figure 2-3), Rotterdam market has positive values of net volatility spillovers in all the time, but the values of net spillovers of Gibraltar, Genoa and Fujairah market tend to be negative over the entire period. In American region (Figure 2-4), net spillovers of Houston market keep positive values except for during 2008, whereas Panama, Philadelphia and Los Angeles market have negative values of net spillovers, namely receiving shocks for the most of periods. The results above indicate that Singapore (Rotterdam/Houston) market are a net transmitter of shocks throughout the sample period in the corresponding region. Altogether, it is evident that Singapore (Rotterdam/Houston) market leads volatility spillovers to the other markets in Asian (European/ American) region.

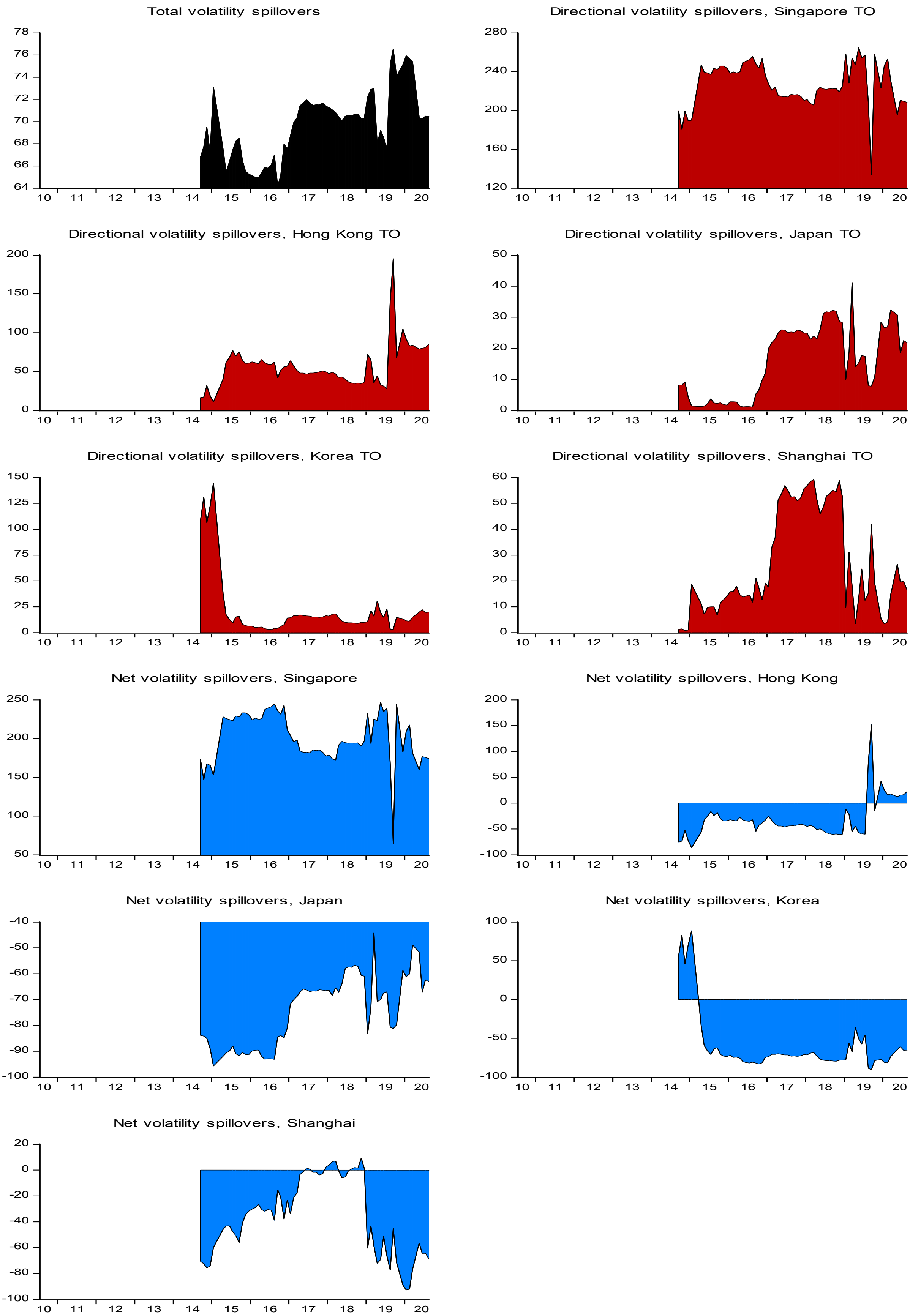


Figure 2-2 Total, directional and net spillover indices of bunker markets in Asian region

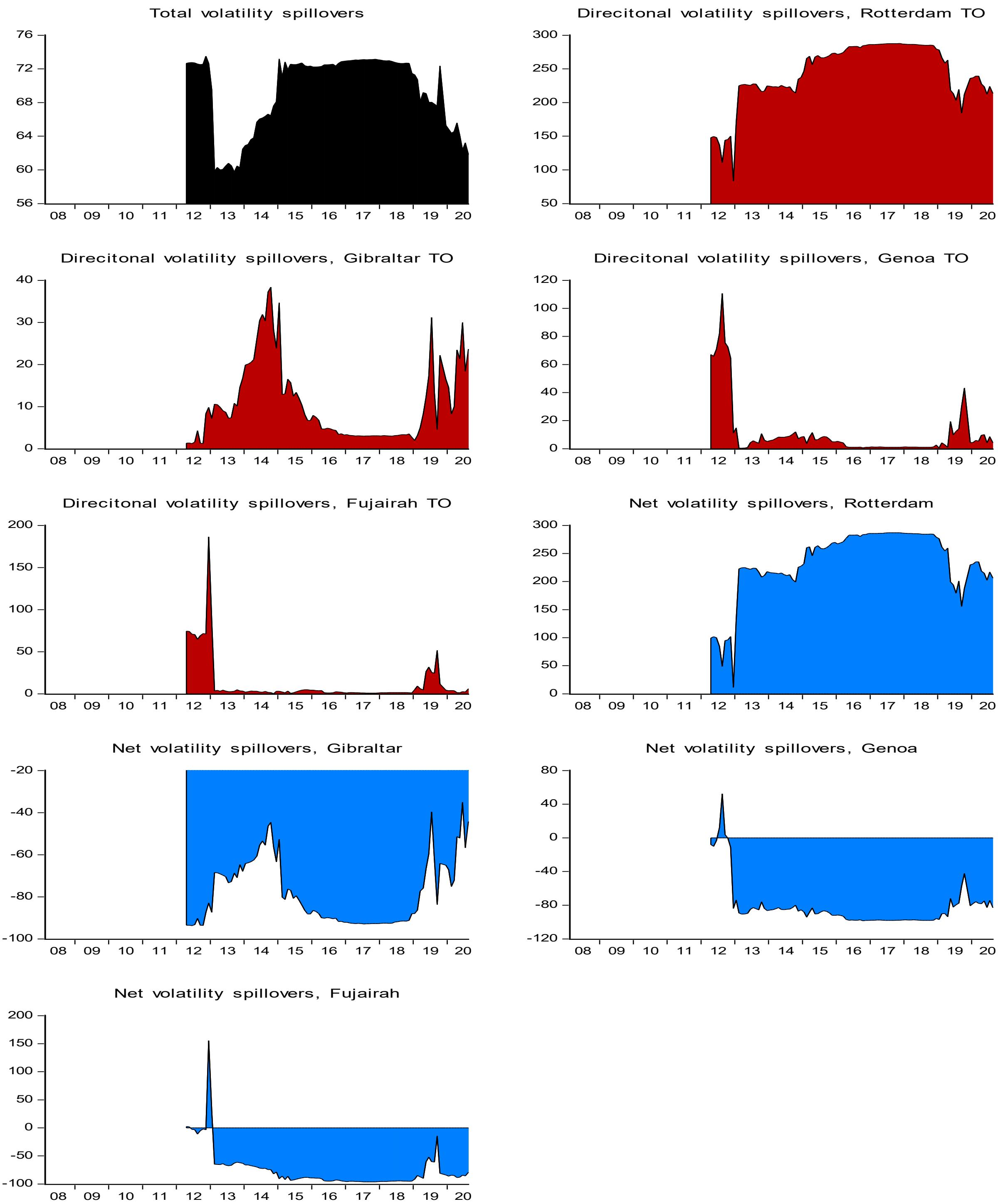


Figure 2-3 Total, directional and net spillover indices of bunker markets in European region

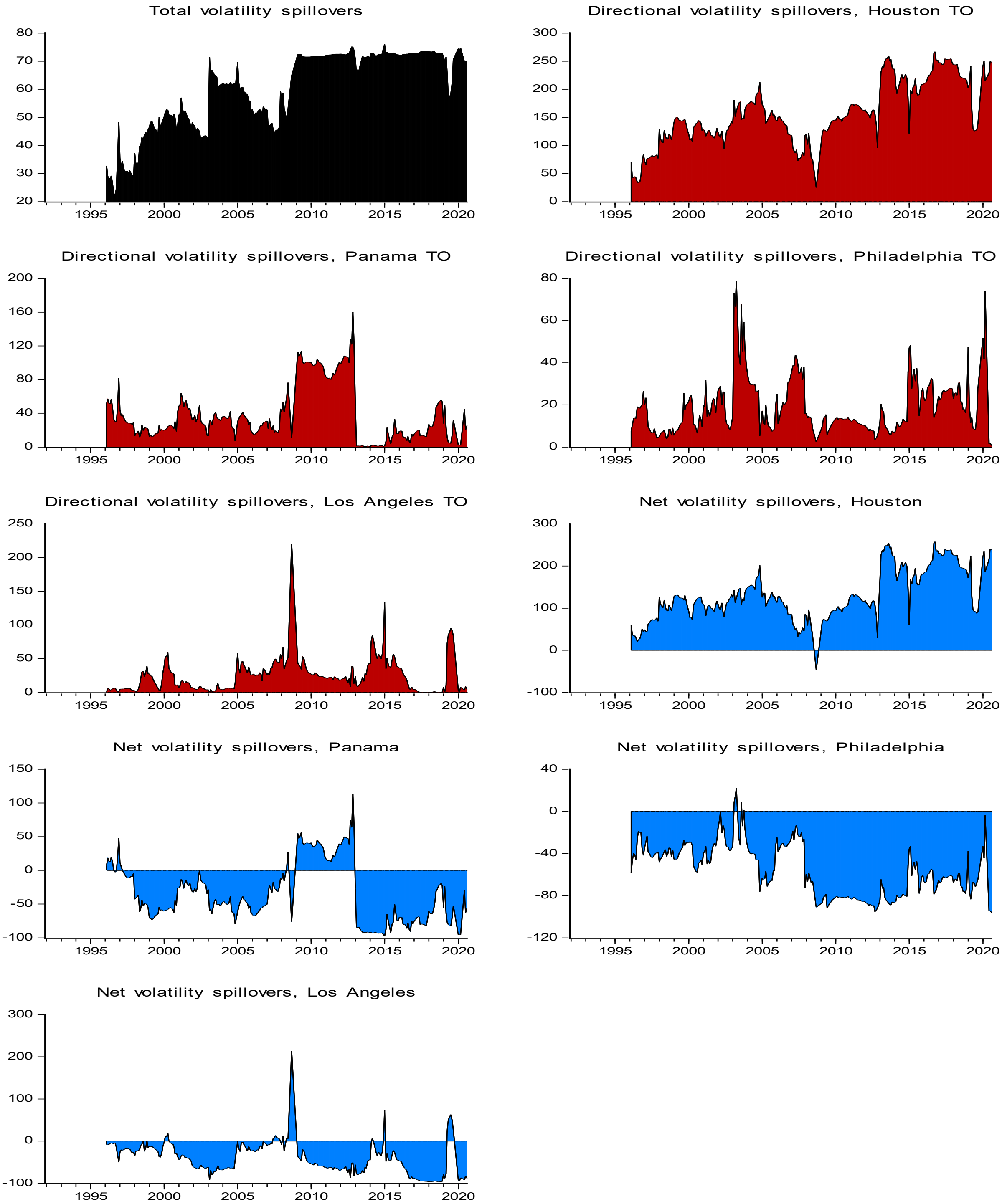


Figure 2-4 Total, directional and net spillover indices of bunker markets in American region

Table 2-3 Volatility spillovers among Singapore, Rotterdam and Houston market

Cross-regions	From (j)			
To (i)	Singapore	Rotterdam	Houston	Contribution From others
Singapore	92.7	0.8	6.5	7.3
Rotterdam	91.6	3.5	4.9	96.5
Houston	91.5	0.9	7.6	92.4
Contribution TO others	183.1	1.7	11.4	196.3
Contribution incl. own	275.8	5.2	19.0	
Net volatility spillovers	175.8	-94.8	-81.0	TSI=65.4%

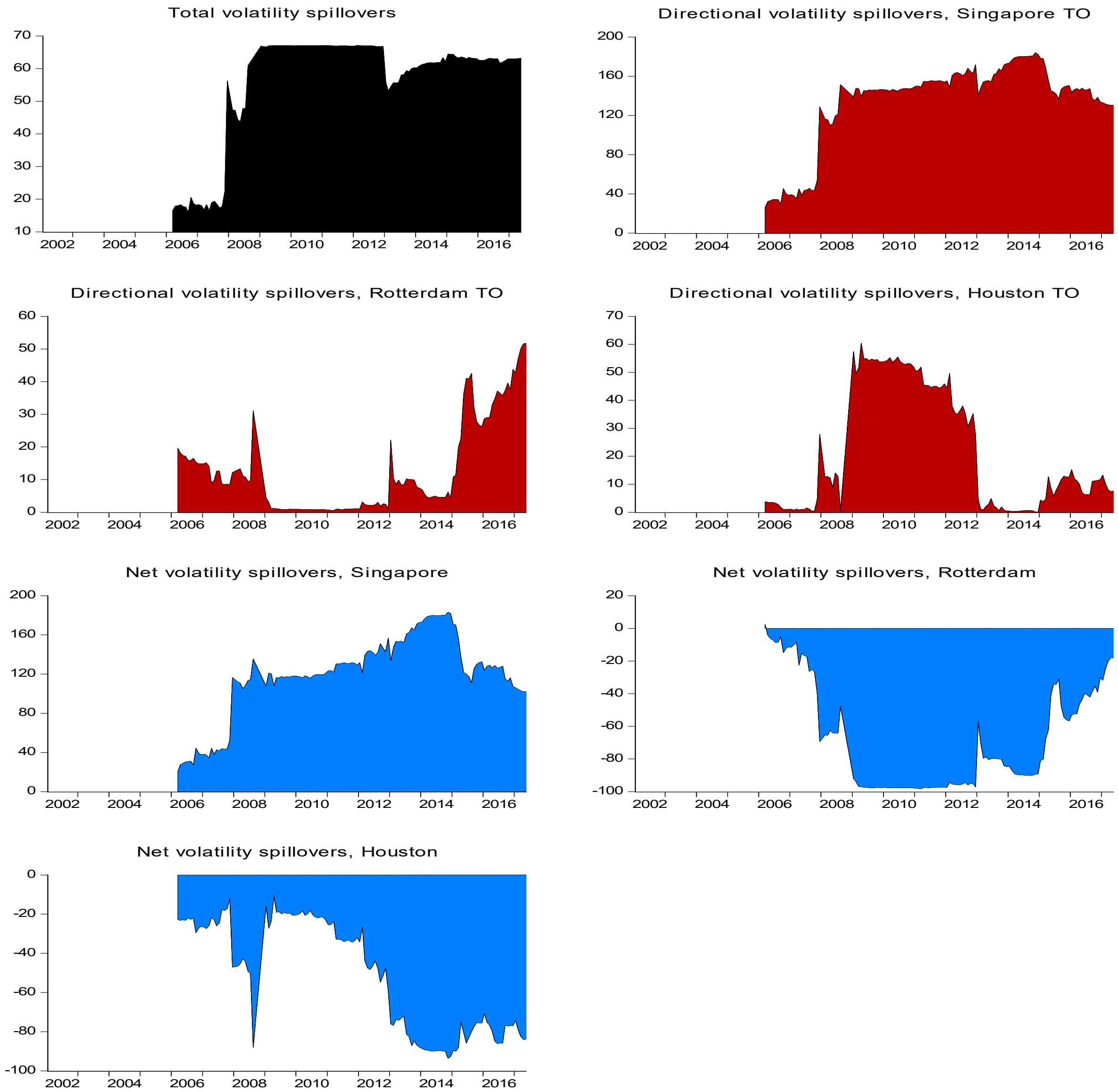


Figure 2-5A Total, directional and net spillover indices among three leading bunker markets - Singapore, Rotterdam and Houston

According to previous results, in Table 2-3, we further examine the cross-region volatility spillovers among the three leading markets: Singapore, Rotterdam and Houston. Table 2-3 reports that Singapore market volatility contributes 91.6% and 91.5% to the forecast error variance of the volatility in Rotterdam and Houston market, respectively. Contrariwise, only 0.8% and 6.5% of the forecast error variance of Singapore market volatility is explained by Rotterdam and Houston market volatility. The result is supported by Figure 2-5A, where Singapore market has a positive value of net volatility spillovers over the whole period. This finding indicates that Singapore market is a more important transmitter of shocks than Rotterdam and Houston market, and Singapore market still plays a leading role in volatility spillovers of the three leading bunker markets. There are some reasons that could explain the leading role of Singapore market in terms of volatility spillovers. Firstly, Singapore, as a transhipment centre due to its strategic geographical location, has by far the largest bunker fuels market in the world, and is regarded as a primary benchmark for the industry (Alizadeh et al. 2004; Alizadeh and Nomikos 2004). Secondly, since the mid-1980s, the Singapore government changed the bunkering market structure from the monopoly, and now Singapore has around 200 shipping lines and connects with over 600 ports (Pinder 1997; Cullinane et al. 2006). Both of those enhance efficient prices and practices in Singapore market, and make Singapore play a leading role in bunker markets. They also suggest that the volatility of Singapore market is deserved to be paid more attention to by market participants. Therefore, in the next subsection the analysis will be provided to further dig into Singapore market, by examining the volatility spillovers between Singapore bunker market and shipping freight markets, as well as between Singapore bunker spot and futures market.

2.5.2. Volatility spillovers between Singapore bunker market and shipping freight markets

The estimation result of the dynamic conditional correlation GARCH model is shown in Table 2-4a, for Singapore market and shipping freight markets. All the dynamic conditional correlation parameters $\rho_{ij,t}$ between Singapore market and shipping freight markets are highly significant at 1% level. The dynamic correlation between Singapore market and CSI (the freight level of the entire shipping market) are negative, and so is it between Singapore market and BCTI (the freight level of clean tanker market); while Singapore market and BDI (the freight level of dry-bulk market) move in the same direction, and it is in line with the movement between Singapore market and BDTI (the freight rate of dirty tanker market). Those findings indicate the complicated correlations between bunker fuel prices and freight rates in different subsectors. It might be caused by the forces of demand and supply in the transportation of dry bulk, crude oil, and other liquid goods according to Alizadeh, Huang, and Dellen (2015).

Table 2-4a Estimation results of the AR(2)-DCC-GARCH model between Singapore bunker market and shipping freight markets

	Bunker and Freight Market				
	Singapore	CSI	BDI	BCTI	BDTI
Panel A: 1-Step, univariate GARCH estimates and univariate diagnostic tests					
constant	73.4691**	504428.8***	21143.08***	186.3294	651.3951**
	[2.19]	[3.00]	[3.11]	[1.50]	[2.55]
θ1	0.7598***	0.2657***	0.2741**	0.1752***	0.2449***
	[4.97]	[3.76]	[2.47]	[3.91]	[3.61]
θ2	0.3495***	0.6822***	0.6439***	0.8468***	0.8164***
	[4.52]	[11.24]	[5.73]	[27.03]	[25.89]
Q(30)	33.747	64.017	42.043	35.388	72.746
	[0.53]	[0.00]	[0.19]	[0.45]	[0.00]
Q^2(30)	27.12	10.916	7.2537	31.211	10.218
	[0.86]	[1.00]	[1.00]	[0.70]	[1.00]
Panel B: 2-Step, correlation estimates and multivariate diagnostic tests					
ρ Singapore-CSI	-0.0692	(-14.69)***			
ρ Singapore-BDI	0.0750	(17.94)***			
ρ Singapore-BCTI	-0.0598	(-13.50)***			
ρ Singapore-BDTI	0.0297	(12.98)***			
ρ CSI-BDI	0.5668	(185.94)***			
ρ CSI-BCTI	0.5849	(283.90)***			
ρ CSI-BDTI	0.6969	(299.67)***			
ρ BDI-BCTI	0.1533	(59.98)***			
ρ BDI-BDTI	0.1184	(53.29)***			
ρ BCTI-BDTI	0.5067	(225.62)***			
α	0.0164(0.02)**				
β	0.9500(0.95)***				
log-likelihood	-7391.4860				
SC	66.7685				
HQC	66.4779				
AIC	66.2811				
Observations	224				
Period	2002M01 to 2020M08				

Notes: $Q(30)$ and $Q^2(30)$ are the Ljung and Box statistics for testing serial correlation with the null hypothesis of no serial correlation in the univariate standardized and squared standardized residuals with 30 lags. * 10% significant. ** 5% significant. *** 1% significant.

Table 2-4b Volatility spillovers between Singapore bunker market and shipping freight markets

	From (j)					
To (i)	Singapore	CSI	BDI	BCTI	BDTI	Contribution From others
Singapore	78.9	5.5	14.4	1.2	0.0	21.1
CSI	9.9	83.8	0.1	0.7	5.5	16.2

BDI	3.6	54.5	38.3	0.9	2.7	61.7
BCTI	10.7	12.6	18.3	55.4	3.1	44.6
BDTI	1.2	23.9	8.7	1.1	65.1	34.9
Contribution To others	25.3	96.4	41.5	3.8	11.3	178.4
Contribution incl. own	104.3	180.3	79.8	59.2	76.4	
Net volatility spillovers	4.2	80.2	-20.2	-40.8	-23.6	TSI=35.7%

Similarly, in order to further explore the relation between Singapore bunker market and shipping freight markets, the volatility series are derived from the DCC-GARCH model. Table 2-4b and Figure 2-5B report the volatility spillovers between pairs of Singapore market, the entire shipping freight market, dry-bulk freight market, clean tanker freight market and dirty tanker freight market. Table 2-4b indicates that Singapore market volatility explains 25.3% of the forecast error variance of the other markets, while 21.1% of the forecast error variance of Singapore market volatility is explained by the other shipping freight markets. And Singapore market contributes 10.7% to the forecast error variance of clean tanker freight market more than to other freight markets. It suggests that Singapore bunker market makes a larger effect on clean tanker freight market in volatility than on other freight markets. The contribution of Singapore market volatility to the forecast error variance of other markets, 25.3%, is weaker than that of the entire shipping freight market, 96.4%. The reason behind this is that the interdependence between Singapore market and freight markets is less than that within freight markets. According to the values of net volatility spillovers, Singapore market, with 4.2%, and the entire shipping freight market (CSI), with 80.2%, are a net transmitter of shocks to other markets, whereas the freight market of dry-bulk (BDI), clean tanker (BCTI) and dirty tanker (BDTI) segment are a net receiver of shocks from others. The negative values of net volatility spillovers result from the contributions of the entire shipping freight market (CSI). It supposes that the shocks to the entire shipping freight market could impact on the subsectors of freight markets, while the shocks to a subsector market have a limited influence on the entire freight market. Furthermore, Singapore market, with 9.9% of net pairwise spillovers, has been a more important transmitter of shocks than the freight market of the entire shipping industry (CSI), with 5.5% of net pairwise spillovers, when considering the effect of shipping freight markets. Thus, Singapore market can notably contribute to the forecasting ability of the entire shipping freight market in volatility.

As shown in Figure 2-5B, the total spillover index and all the directional spillovers experience notable variation over time; and net spillovers of Singapore market, the entire freight market, dry-bulk freight market, clean tanker freight market and dirty tanker freight market vary between positive and negative values during the sample periods. It suggests that the identified spillovers are sensitive to time-specific events. For example, Singapore market is a net transmitter of shocks to other freight markets between the year of 2006 and2008, and then becomes a net receiver of shocks from the year 2008 to 2012; after that, the tendency is commonly fluctuated in the following period. Differently, the net spillovers of the entire shipping freight market (CSI) tend to be positive in the most of time, mainly transmitting volatility to all the other markets. Remarkably, the net volatility spillovers switch with time-specific events. For instance, with the impact of global financial crisis, Singapore market leads the entire shipping freight market in volatility as the net spillovers of Singapore market (the entire shipping freight market) are positive (negative) in the year 2008; from the year 2020 – when the COVID-19 broke out over the world – the entire shipping freight market becomes a net receiver of shocks from other markets with the negative value of net spillovers.

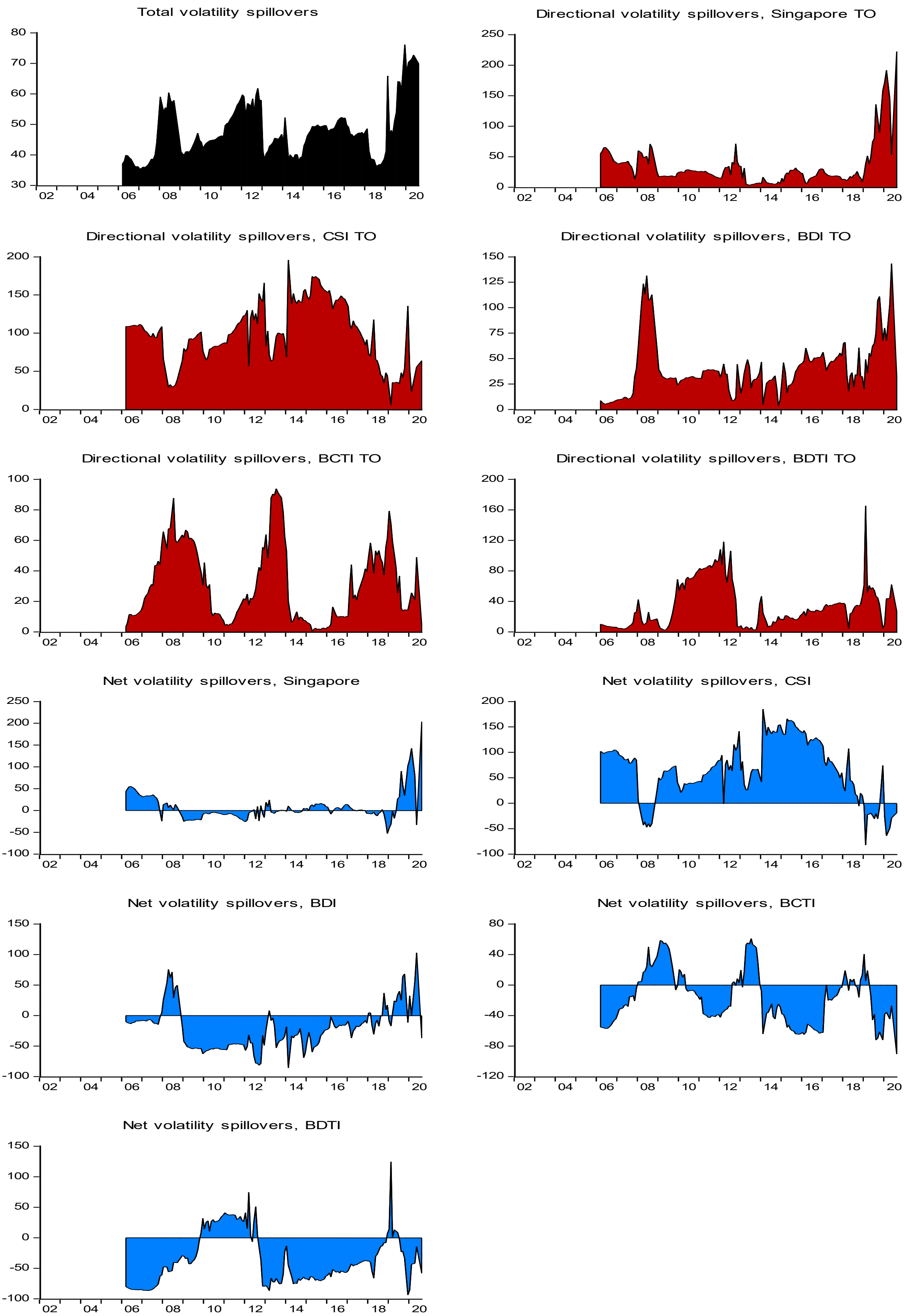


Figure 2-5B Total, directional and net spillover indices among Singapore bunker market and freight markets

2.5.3. Volatility spillovers between bunker spot and futures markets

As shown in Table 2-5a, the AR(2)-DCC-GARCH model between Singapore bunker spot and futures market is empirically estimated to obtain the volatility series. The dynamic correlation parameter between Singapore bunker spot and futures market, 0.8921, is distinctly high, illustrating that the two markets are closely connected with each other. Table 2-5b presents the decomposition of spillovers between Singapore bunker spot and futures volatility. Singapore spot volatility is responsible for 76.6% of the forecast error variance of Singapore futures volatility, while Singapore futures volatility accounts only for 10.8% of the forecast error variance of Singapore spot volatility. It proves the unidirectional spillovers in volatility from Singapore spot market to futures market, which is also supported by the positive net volatility spillovers of Singapore spot market in Figure 2-5C. Put differently, shocks to Singapore spot volatility tend to have much larger contributions to Singapore futures volatility. Market-wide information spreads and causes less variance in Singapore futures market than in Singapore spot market. It means that Singapore futures market cannot adjust well in regard to market news just as Singapore spot market, making price discovering of Singapore futures market ineffective. Generally, the related literature suggests that spot and futures market adjust similarly with regard to the market-wide news (Antonakakis, Floros, and Kizys, 2016; Tao and Green, 2012). It is worth noting that this result is in opposition with the relevant financial literature (Antonakakis, Floros, and Kizys, 2016), suggesting that Singapore futures market is inferior in hedging risks, compared to other financial derivatives markets.

Table 2-5a Estimation results of the AR(2)-DCC-GARCH model between Singapore bunker spot and futures market

	Singapore Bunker Spot and Futures Market	
	Singapore Spot	Singapore Futures
Panel A: 1-Step, univariate GARCH estimates and univariate diagnostic tests		
constant	0.0004*	0.0004*
	[1.77]	[1.77]
θ1	0.7495***	1.0141***
	[4.10]	[4.10]
θ2	0.4053***	0.2737**
	[4.49]	[2.56]
Q(30)	25.1880	40.0400
	[0.89]	[0.26]
Q^2(30)	25.2230	27.9750
	[0.91]	[0.83]
Panel B: 2-Step, correlation estimates and multivariate diagnostic tests		
ρ Singapore Spot-Futures	0.8921 (107.10)***	

α	0.1375 (3.77)***
β	0.7847 (12.10)***
log-likelihood	597.0287
SC	-6.4244
HQC	-6.5417
AIC	-6.6218
Observations	177
Period	2005M11 to 2020M08

Notes: $Q(30)$ *and* $Q^2(30)$ are the Ljung and Box statistics for testing serial correlation with the null hypothesis of no serial correlation in the univariate standardized and squared standardized residuals with 30 lags. * 10% significant. ** 5% significant. *** 1% significant.

Table 2-5b Volatility spillovers between Singapore bunker spot and futures markets

	From (j)		
To (i)	Singapore Bunker Spot	Singapore Bunker Futures	Contribution From others
Singapore Bunker Spot	89.2	10.8	10.8
Singapore Bunker Futures	76.6	23.4	76.6
Contribution TO others	76.6	10.8	87.4
Contribution incl. own	165.9	34.1	
Net volatility spillovers	65.8	-65.8	TSI=43.7%

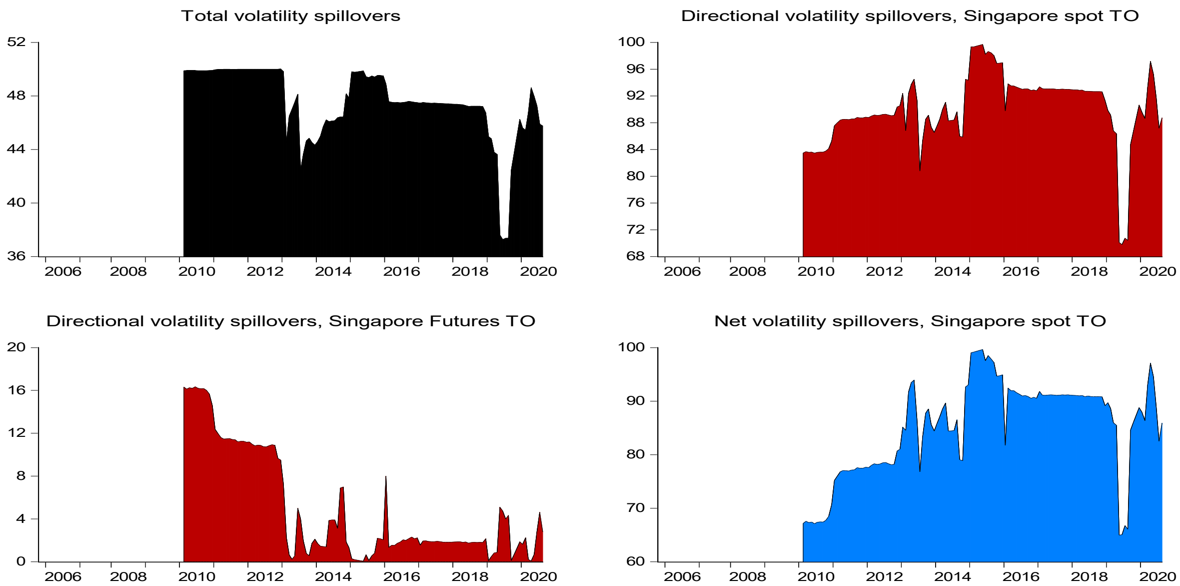


Figure 2-5C Total, directional and net spillover indices between Singapore spot and futures market

2.6 Conclusions

This chapter's objective is to investigate the dynamic interdependence among bunker markets, across bunker markets and freight markets, between bunker spot and futures market. Referring to the large and persistent volatility in bunker markets, it is crucial for operational and financial risk hedge to approach the issue of volatility spillover effects with bunker markets, between Singapore market and freight markets, and between Singapore bunker spot and futures market. In our study, the DCC-GARCH specification is utilized to capture the dynamic conditional correlations among bunker markets and across different markets; then, volatility series are derived from the previous specification, and the variance decomposition model is used to explore static and dynamic volatility spillovers. Particularly, the existence, magnitude and direction of volatility spillovers are identified over time. The study can be employed to improve predicting ability of the volatilities among bunker markets, freight markets and futures market.

This study fills the gap in the previous studies regarding the magnitude and direction of volatility spillovers among multiple bunker spot markets. Furthermore, freight markets and bunker futures market are incorporated into the exploration of volatility spillovers across bunker market and other relevant markets, making risk measures more accurate. Additionally, the empirical dynamic results disclose the interesting information in volatility spillovers over time, and confirm that the identified spillovers are time- and event-specific. Hence, it suggests that market participants and stakeholders should adjust their hedging strategies in response to crucial events in particular markets, such as the global financial crisis and the COVID-19 pandemic, in order to manage risks linked with their operational and economic activities.

The findings of this study have important implications for shipowners, charterers, bunker traders, investors, and regulators. Specifically, the dynamic volatility spillovers among bunker markets are associated with the fluctuations in other bunker markets. The time-variant interdependence across different markets also influences significantly aggregate risk exposures for bunker markets. Put differently, one bunker market is exposed to fluctuations of the other bunker markets, freight markets and bunker futures markets. In light of the spillover effects from various markets volatility, market participants could have a more comprehensive understanding of risk dissemination across markets and improve risk hedging accordingly. In addition, Singapore market acts as a leading bunker market to transmit volatility to other bunker markets and Singapore futures market. Therefore, traders could utilize the fluctuations in Singapore market to foresee the volatilities in other bunker markets, shipping freight markets and bunker futures markets. And risk hedgers could improve their portfolios to be more efficient according to aggregate risk exposure. For policy makers, they could monitor the fluctuations in Singapore market against potential risks so as to develop local markets steadily.

Chapter 3
The Role of Shipping Credit Spread in Shipbuilding Market

3.1 Introduction

Shipping bond financing has become more common and popular since the mid of 1990s. In spite of the fact that public equity is also an alternative of capital funding, only the large and well-established shipping companies could obtain financing from shipping stock market, such as AP Moeller Maersk, MOL and NYK. Nowadays market participants could have much easier access to shipping bond market, with increasingly shipping companies' changing from family business to modern corporations.

The majority of shipping bonds falls into the high-yield grade since shipping industry is highly volatile and capital intensive. The shipping bonds issued by global shipping companies have a yield of hundreds of basic points above the risk-free rate to the industry risk compensation. Generally, the yield of shipping bonds is commonly in a range from 7% to 9%; and under weak market conditions and issuers, it could be up to 12% and even more for bearing risks (Karatzas, 2016). Notwithstanding, shipping bonds is still an alternative to finance for purchasing ships, especially during the bank loan shortage periods. Firstly, the interest payment in bond financing is regarded as the cost in an income statement, and thus it could help to reduce the amount of tax by shipping companies. Also, for publicly listed shipping companies with important market shares, they could employ their own creditworthiness and relationship with institutional investors to finance easily and flexibly (Stopford, 2009). Additionally, for those private shipping companies which do not prefer IPO, bond financing is an alternative to have access to capital market funding.

Shipping is an asset-heavy industry, with ships being complicated assets that could cost more than $150 million to build by raising the required funds (Drobetz, Haller, and Meier, 2016). Thus, shipbuilding market, featured with highly capital-intensive, is associated with shipping bond market via financing. As mentioned above, bond financing from financial institutions and investors becomes a popular and practical means to purchase vessels and fund other activities in shipbuilding market. Prior literature rarely emphasized on the relation between the shipping bond financing market and shipbuilding market. Most of previous studies on shipping financing and bonds still focused on the determinants of the performance of shipping financing and bonds; on the assessment and determined factors of credit rating and default of shipping bank loans and bonds (Grammenos, Nomikos, and Papapostolou, 2008); on factors affecting the pricing of shipping bonds and determining shipping bond spreads. Kavussanos and Tsouknidis (2014) investigated factors influencing the changes of shipping bonds spreads. Therefore, this study aims to fill the research gap by exploring the role of shipping bond market and shipping credit spread in shipbuilding market.

The objective of this study is to enhance the thin literature on shipping bond market and shipping credit spread. This study focuses on investigating what a role shipping credit spread plays in shipbuilding market, and whether shipping credit spread is an important determinant of shipbuilding activities . The contributions of our study to the existing shipping literature are as follows. We firstly construct a financial indicator in shipping market, shipping credit spread, and then identify that shipping credit spread significantly impacts on shipbuilding market. It indicates that predictive contents in shipping credit spread carry crucial information and signals for the activities of shipbuilding market. Secondly, we reveal that before and after the onset of the global financial crisis shipping credit spread has a different influence on shipbuilding market. Thirdly, this study discovers that the indicator of shipping bond market plays a more significant role in predicting the fluctuations of shipbuilding market than that of shipping loan market. Finally, it shows that there exist asymmetric effects on shipbuilding market in terms of changes in shipping credit spread.

The rest of this chapter is organized as follows. The next section provides the literature review and the methodology, displaying the construction of shipping credit spread and the econometric model specification. Section 3.3 describes the dataset employed. Section 3.4 analyses the results of this study, whereas section 3.5 discusses the main findings. Section 3.6 derives conclusions.

3.2 Literature review and methodology

Based on the theories of financial frictions, this study hypothesizes that there exist financial market frictions. There are vast studies on credit spreads and real economy. For instances, Harvey (1988), Estrella and Mishkin (1998), and Hamilton and Kim (2002) examined spreads between long-term and short-term interest rates and real economy; Ang et al. (2006) investigated the yield curves of the Treasuries and GDP growth; Gertler and Lown (1999), Mueller (2009), Gilchrist, Yankov and Zakrajšek (2009), and Faust et al. (2013) concerned the yield spreads on corporate bonds and economic fluctuations. Friedman and Kuttner (1992,1998) and Emery (1996) focused on the information content of the spreads between the commercial papers and the Treasury-bills. Those studies treat credit spreads as financial indicators, carrying the information on the evolution of economic activity. However, the aforementioned studies only consider general credit spreads in a more macro-economy or large-scale economy system, and do not consider credit spreads in an industry level or market level. Specifically, shipping is an industry characterized as being highly volatile, capital intensive and highly geared. The volatile nature of shipping industry generates the substantial uncertainty of cash flows of shipping companies to service debt repayments, and further undertaking those risks is required to be compensated with higher credit spreads (Kavussanos and Tsouknidis, 2014; Grammenos and Arkoulis, 2003). Hereby, general credit spreads would be inefficient to explain economic activities in shipping industry. Therefore, this study addresses the shortcoming above by constructing a new credit spread for shipping industry.

Shipping credit spread, the difference between corporate bonds yield and government bonds yield with comparable maturity, is constructed to reflect the fluctuations in shipping bond market. The intrinsic characteristic of global shipbuilding market is remarkably capital intensive, deeply relying on funds and financing (Haralambides, Tsolakis and Cridland, 2005). Hence, in the following part shipping credit spread is utilized to examine the way and extent shipping bond market impacts on shipbuilding market. Knowing the way and extent shipping credit spread influences on shipbuilding market could provide market players precious insights for market conditions and the timing of investment.

Furthermore, the growth and development of shipbuilding market is tightly associated with the crests and slumps of global economy and trade (Hossain and Zakaria, 2017). The global financial crisis, beginning from the year of 2007, has hit world economy heavily. Thus, it is worthy to examine whether there is a difference in how shipping credit spread affects shipbuilding market between before and onset of the financial crisis, respectively.

In addition, shipping bank-loan is a traditional method of funding and still plays a significant role in shipping industry. López-Salido, Stein, and Zakrajšek (2017) argued that bond markets have the ability to signify changes in the real economy more accurately than other capital markets. Thus, this study investigates the role of shipping credit spread as a financial indicator by comparing the effects of shipping bond market and shipping loan market on shipbuilding market, respectively.

Importantly, we have a larger sample size of global shipping bonds, compared with that used in previous studies. Preceding studies on shipping bonds fell into the period from 1980 to 2010. There is lack of the newest research on shipping bonds over the last decade, which is filled by this study. Also, Fridson and Garman (1998) stated that when studying the spreads of high-yield bonds, it is important to categorize the underlying by industry or sector for the purpose of avoiding biased estimation. So, this study adopts sector-wise classification in global shipbuilding market, and explores dry bulk, tanker, container, and offshore segment in shipbuilding market.

This study aims to investigate what a role shipping credit spread plays in shipbuilding market, and whether shipping credit spread is an important determinant of shipbuilding activities. To address the research question, we firstly construct a financial indicator in shipping market, shipping credit spread; Secondly, we utilize econometric models to examine the role of shipping credit spread in shipbuilding market.

3.2.1 Shipping credit spread

We hypothesize that when economic forces influences the tonnage of shipbuilding contracts, shipping credit spread as a newly added determinant impose an important effect on shipbuilding activities.

Firstly, shipping credit spreads in shipping bond market is constructed, referring to previously financial studies.

Consider a shipping bond m issued by firm i at time t, which expects to have a sequence of cash out-flows $\{A(h) = 1,2, \dots, H\}$. The price of the bond m contains the regular coupon payments and the repayment of the principal at maturity, given by,

$$P_{m,i,t} = \sum_{h=1}^{H} A(h) D_h(t), \tag{3-1}$$

where $D_h(t)$ is the function of the discount rate for the cash flow h at time t. With the cash flow and the maturity of the shipping bond m, the corresponding Treasury (risk-free) bond could be selected and obtained, denoted by $y_{m,t}^{f}$. And the credit spread of a shipping bond m could be simply derived by the difference of the yield of a shipping bond, $y_{m,i,t}$ and the yield of a Treasury security, $y_{m,t}^{f}$.

$$CS_{m,i,t} = y_{m,i,t} - y_{m,t}^{f}\ , \tag{3-1}$$

where $CS_{m,i,t}$ is the credit spread of a shipping bond m issued by firm i at time t, $y_{m,i,t}$ is the yield to maturity of a shipping bond m issued by firm i at time t, and $y_{m,t}^{f}$ is the yield of the risk-free security for each shipping bond m at time t. The data of the yield to maturity, $y_{m,i,t}$, for shipping bonds are available to be collected. The data of the yield of a risk-free bond, $y_{m,t}^{f}$, is acquired by the US treasury bond with the similar maturity to the underlying shipping bond m. It is common to treat the US treasury bond as a risk-free bond in the financial field, and it is broadly used in the studies of credit spreads. Referring to Gertler and Lown (1999), Mueller (2009), Gilchrist, Yankov and Zakrajšek (2009), and Faust et al. (2013), this study also takes the US treasury bond as a risk-free bond to study shipping credit spread.

By utilizing the micro-level dataset of all shipping bonds, a simple shipping credit-spread index is constructed as

$$CS_t = \frac{\sum_i \sum_m CS_{i,m,t}}{N_t}, \quad (3\text{-}2)$$

where N_t is the number of shipping bonds of all firms in time t, and CS_t denotes shipping credit spread, an arithmetic average of the credit spreads on all shipping bonds in a given time t.

In addition, by the micro-level data of shipping loans, an arithmetic average amount of shipping loans in each year, denoted by LO_t, is utilized to indicate shipping loan market.

3.2.2 Econometrical model specification

Secondly, the following panel data dynamic regression model is utilized to examine the effect of shipping credit spread on shipbuilding market:

$$y_{it} = \sum_{h=1}^{H} \alpha_h * Contracts_{i,t-h} + \sum_{g=0}^{G} \theta_g * CS_{i,t-g} + \sum_{k=0}^{K} \beta_k * FR_{i,t-k} + \sum_{j=0}^{J} \gamma_j * SH_{i,t-j} + \sum_{l=0}^{L} \lambda_l * OS_{i,t-l} + u_i + e_{it}, \quad (3\text{-}4)$$

Where:

- y_{it} is the dependent variable, the tonnages of newbuilding contracts observed for individual sector i at time t.
- $\text{Contracts}_{i,t-h}$ is the lag h of current newbuilding contracts, $h \geq 1$; $CS_{i,t-g}$ denotes shipping credit spread and its lag terms, $g \geq 0$; $FR_{i,t-k}$ denotes freight rates and its lag terms, $k \geq 0$; $SH_{i,t-j}$ denotes secondhand price and its lag terms, $j \geq 0$; $OS_{i,t-l}$ denotes the ratio of orderbook over global fleetsize and its lag term, $l \geq 0$.
- $OS_{it} = \frac{Orderbook_{it}}{Fleetsize_{it}}$;

- $Orderbook_{it}$ includes the accumulated deadweight of vessels under the construction in sector i at time t, which have not been delivered to owners and remain on the orderbook;
- $Fleetsize_{it}$ is the available tonnage of fleet in shipping sector i at time t.
- $\alpha_h, \theta_g, \beta_k, \gamma_j, \lambda_l$ are the parameters of all independent variables.
- u_i is the unobserved time-invariant individual effect.
- e_{it} is the error term, following a distribution with mean zero and variance σ^2.

In order to best assess the effect of shipping credit spread on shipbuilding market, the following variables are also considered as control variables into Equation (3-4). The variable of freight rates is the time charter equivalent (TCE) rate and used to reflect market profitability during a period, which could give an indication of forward expectations in shipping and shipbuilding market.

Secondhand price is also a major determinant of newbuilding ships. Secondhand market is blended with newbuilding market and secondhand vessel is a close substitute of new ships (Strandenes, 1986). Helpman (1987) argued that when the price of secondhand vessels rises, it would result in the increase of demanding newbuilding vessels. Hence, the variable of secondhand price is incorporated into our control variables.

Shipyard capacity is a significant determinant of shipbuilding output and market (Helpman, 1987). OS ratio is the ratio of the orderbook over the fleetsize, usually used as a proxy to measure shipyard capacity. According to Haralambides, Tsolakis and Cridland (2005), a higher OS ratio indicates a tighter shipyard capacity for their conducting vessel constructions. Thus, OS ratio is expected to negatively relate with newbuilding contracts. More importantly, when the OS ratio enlarges, there is a possibility that substantial fleets would enter into shipping market in a short future, consequently weakening the market revenues and the orders for newbuilding ships or newbuilding contracts. In other words, shipbuilding market would shrink and become tense with a higher OS ratio.

The model also includes the lags of the newbuilding contracts as covariates and contains unobserved sector fixed effects, u_i. The inclusion of lag dependent variable as a regressor makes an econometric model dynamic, which generates the endogeneity problem simultaneously. Thus, it is better to use the generalized method of moments (GMM) to deal with the endogeneity problem.

3.3 Data

This study adopts panel data to study how shipping credit spread plays a role in shipbuilding market. The dataset consists of yearly newbuilding contracts, freight rates, shipping credit spread, second-hand price of vessels, orderbook, fleetsize, and shipping loans. The dependent variable, newbuilding contracts, is measured by the deadweight tonnage of ships newly purchased in shipbuilding market in each year. The data of newbuilding contracts, freight rates, second-hand price of vessels, orderbook, and fleetsize across four sectors (dry bulk, tanker, container, and offshore sector) are collected from Shipping Intelligence Network (SIN) database, running from 1996 to 2018. The data of shipping bonds is sourced from Bloomberg database (Bloomberg, 2018) during the period between 1996 and 2018;and the data of shipping bank loans consists of 2,110 loans issued during the period of June 2000 to August 2018, collecting from Bloomberg database (Bloomberg, 2018). Figure 3-1 plots the variations of the market value of shipping bonds issued, the market value of shipping loans issued, and the tonnage of newbuilding contracts over time, which provides a brief view of the trends and relationship among shipping bond market, shipping loan market and shipbuilding market.

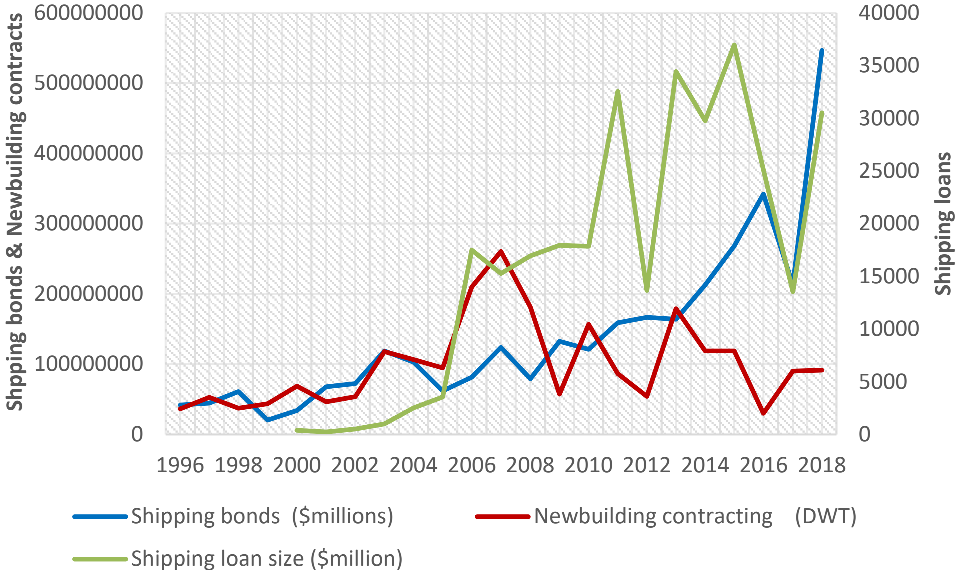


Figure 3-1 Plots of shipping bonds, shipping loans and newbuilding contracts

The key point is constructing the variable, shipping credit spread. In our bond data, shipping bonds are those issued by shipping companies, mainly running a business in shipping industry. Shipping credit spread in this study is the difference between corporate bonds yield and government bonds yield with comparable maturity. The corresponding US Treasury rate is taken as the yield of a risk-free bond. The data of shipping bonds is filtrated from more than nine thousands transportation bonds before 31st Dec 2018. And then we eliminate those bonds without issue/maturity date and those without yield to maturity. Also, we delete those bonds with an extreme credit spread, whose basis points are larger than 5,000 or are lower than 5. Those observations only account for a tiny number of our data. Referring to Gilchrist and Zakrajšek (2012), credit spreads less than 5 basis points and above 5000 basis points are classified as the extreme observations. In order to ensure that our results are not driven by a small number of extreme observations, we also delete those extreme observations. Finally, this study has 1756 shipping bonds with credit spreads during the period from 1996 to 2018, following the selected criteria above. Those micro-level shipping bonds enable us to construct shipping credit spread. By using the micro-level data of shipping bonds, an arithmetic average credit spread of shipping bonds in each year could be derived. By utilizing the micro-level data of shipping loans, an arithmetic average amount of shipping loans in each year could be obtained.

Table 3-1a Summary Statistics of Variables

Variable	Description (Unit)	N	Mean	SD	Min	P50	Max
Contracts	Newbuilding contracts (million DWT)	92	23.26	27.58	0.48	14.03	161.2
FR	Freight rate ($/day)	81	19194	12200	5070	15595	54182
CS	Credit spreads (basis points)	92	641.2	108.7	424.1	650.9	915.3
SH	Secondhand price index	92	119.8	62.32	24.72	110.3	462.2
Orderbook	Orderbook (million DWT)	92	61.76	70.89	1.079	40.42	328.9
Fleetsize	Fleetsize (million DWT)	92	248.9	218.1	5.773	250	821.5
OS	OS ratio (pct.)	92	0.309	0.206	0.0752	0.239	0.965
LO	Shipping loans (MM dollars)	76	163.327	123.277	2.4	169.538	369.663

Note: Sample period:1996-2018;
OS ratio is the ratio of orderbook over fleetsize.

Table 3-1a presents the descriptive statistics for all the variables in our study. The distribution of shipbuilding contracts is positively skewed, with the range from $0.48 million DWT to $161.2 million DWT. The Credit spreads and fleetsize conform similarly to the normal distribution. The distribution of freight index, orderbook and OS (orderbook to fleetsize) ratio exhibit a significant positive skew, as in most of time the freight rate and orderbook cannot reach their average level and in some points the freight rate and orderbook are much higher than corresponding average level.

Table 3-1b Summary Statistics of Shipping Bonds Characteristics

	Mean	SD	Min	P50	Max
Number of bonds per year	76.3478	35.6149	11	73	146
Market capitalization of issuers ($thousands.)	1000843.45	2745446.531	27.0585	28647.3886	20366784.1
Amount issued ($mil.)	117.395	177.8364	0.0434	51.488	1948.973
Maturity at issue (years)	4.1539	3.5404	0.0219	3.0007	27.7509
Coupon rate (pct.)	6.4598	3.6699	0.07	6.02	26.27
Yield to maturity (pct.)	8.7506	5.8323	2.1606	7.4899	49.4668
5-year default probability	0.0826	0.0849	0.005	0.0561	0.4363

Note: Sample period:1996-2018; Number of bonds=1756.
P50 denotes median numbers.
Higher default probability means higher default risks.

Table 3-1b presents summary statistics for the key characteristics of shipping bonds in our study. The median number of shipping bonds issued is 73 issues per year, and there are around 76 issues in any given year. The distribution of the market capitalization of issuers is significantly positive skewed, with the range from $27.1 million to around $20,367.8 billion. The range of the amount issued of those shipping debt instruments is fairly large, running around from $0.04 million to $1,948.97 million. The maturity of those shipping bonds runs from 0.02 year to 27.75 year, with the average maturity at issue of 4.15 years. The maximum of the coupon rate in those shipping debt instruments reaches at 26.27%, and the average of the yield to maturity is at 8.75%, relatively higher than that in other industries or markets. In term of the 5-year default probability, the median value is about 5.61%, and the distribution also exhibits a significant positive skewness.

Table 3-1c Summary Statistics of Shipping Loans Characteristics

	Mean	SD	Min	P50	Max
Number of loans per year	111	76.6355	3	122	237
Loan size ($mil.)	148.0543	283.7742	0.7	75	8715.07
Maturity at issue (years)	8.2624	4.0243	0.0082	7.0883	42.0007
Loan payment rank	-	-	Sub. Unsecd	-	1L Sr. Secd
Loan fixed rate (pct.)	4.9507	2.9606	0.9	4.45	12
Loan floating margin (basis point.)	238.9548	107.4452	0	240	800

Note: Sample period: 2000-2018; Number of loans=2,110. P50 denotes median numbers.
Loan floating rate=loan base rate +loan floating margin; loan base rate could be LIBOR, and US LIBOR.
Sub. Unsecd: Subordinated Unsecured; 1L Sr. Secd: First-Lien Senior Secured.

Table 3-1c summarizes the primary characteristics of shipping loans in our sample. The number of shipping loans issued per year is 111 issues with the average maturity of 8.26 years, and this distribution shows significantly negative skewed. The average size of shipping loan reaches \$148 million, with the large range spanning from \$0.7 million to \$8,715.07 million. For shipping loans with a fixed coupon, the largest rate is at 12%; for shipping loans with a floating rate, an average loan has an expected return of 238.95 basis points above loan base rate.

3.4 Results

The equation (3-4) is estimatde to examine the effect of shipping credit spread on shipbuilding market. The lag selection for fundamental variables is based on the corresponding theories of maritime economics. The effects of the fundamental variables (freight rate, and secondhand price and OS ratio) on shipbuilding market diminish one year later. Hawdon (1978) employed current and lagged freight rates and other variables to study new tanker market. Also, Xu, Yip, and Liu (2011) proved that the freight market continues to affect newbuilding market in about one year. Dai et al. (2015) found that the lagged shocks in secondhand price will cause volatility changes in newbuilding price in the dry bulk market. The argument of Jin (1993) is that shipowners respond to current market conditions, and it would take them about one year to manifest their decisions on the orderbook. In our specifications, it is found that the lag one of dependent variable, the current and one-year lagged freight rate, second-hand price, OS ratio, and the two-year lagged of shipping credit spread have a better estimation on shipbuilding market. The coefficients of the one-year lagged and the three-year lagged of shipping credit spread, as well as other lags of fundamentals are not significant, and thus are not included in our regressions. Also, the test of joint significance shows that all control variables involved in this econometric model are jointly significant. That is, all controlling variables have jointly a good ability to explain the change of the dependent variable, the newbuilding contracts.

Since the dynamic regression model contains the endogenous variables, the generalized method of moments (GMM) is utilized to estimate our regression models. Although the estimators of pooled OLS and fixed effects model are biased in a dynamic panel model, pooled OLS and fixed effect model could ensure the bounds of all real estimators. Table 3-2 shows the detailed estimated results. Column (1) and (5) present coefficient estimations of the pooled OLS and the fixed effect model. The first-difference GMM and the system-GMM are displayed in column (2) and in column (3) respectively, considering the endogenous variables in the model. The first-difference GMM estimators only adopt the lag terms of level variables as instruments variables; while the system-GMM consider both of the lag terms of level and differenced variables as instruments, solving the weak instruments problem of the lag terms of level variables. The column (4) is the biased-corrected least squares dummy variable (LSDVC) estimator. This estimator is suitable when individual i is small in a model, but the premise of adopting LSDVC estimator is that all control variables in the model should be strictly exogenous. In reality, this assumption cannot be satisfied when the explanatory variables are impacted on by external shocks. This endogeneity problem would make our LSDVC estimator biased. In summary, the system-GMM in column (3) could have a better estimation of the effect of shipping credit spread on shipbuilding market.

Table 3-2 Model estimations

	(1)	(2)	(3)	(4)	(5)
		First-Difference-	System-		
	OLS	GMM	GMM	LSDVS	FE
$Contracts_{t-1}$	0.266***	0.184	0.266***	0.260***	0.184*
	(2.69)	(1.62)	(2.86)	(3.47)	(1.71)
FR_t	0.043	0.063***	0.043*	0.035	0.063**
	(1.55)	(4.73)	(1.65)	(1.4)	(2.05)
FR_{t-1}	-0.099***	-0.082**	-0.099***		-0.082***
	(-3.95)	(-2.46)	(-4.21)		(-2.89)
CS_{t-2}	-0.030*	-0.030**	-0.030*		-0.030*
	(-1.70)	(-2.00)	(-1.81)		(-1.73)
CS_t				0.01	
				(0.55)	
SH_t	0.246***	0.231***	0.246***	0.234***	0.231***
	(5.57)	(15.42)	(5.93)	(3.98)	(4.7)
SH_{t-1}	0.140**	0.145**	0.140***		0.145**
	(2.52)	(2.29)	(2.68)		(2.54)
OS_t	-70.926***	-78.456***	-70.926***	-20.69	-78.456**
	(-2.70)	(-4.64)	(-2.87)	(-0.87)	(-2.52)
OS_{t-1}	48.584**	66.644***	48.584**		66.644***
	(2.07)	(4.52)	(2.2)		(2.73)
cons	12.18	4.855	12.18		4.855
	(0.93)	(0.69)	(0.99)		(0.36)
N	74	70	74	78	74
sargan			73.495		
sar df			65		

F	26.782	17.165

t statistics in parentheses;

* p < 0.1, ** p < 0.05, *** p <0.01

Table 3-3 Dynamic panel model on the effect of shipping credit spread on shipbuilding market

	(1) Shipping credit spread	(2) Control variables	(3) All variables
$Contracts_{t-1}$	0.575***	0.304***	0.266***
	(6.42)	(3.3)	(2.86)
CS_{t-2}	-0.048**		-0.030*
	(-2.00)		(-1.81)
FR_t		0.043	0.043*
		(1.64)	(1.65)
FR_{t-1}		-0.096***	-0.099***
		(-4.02)	(-4.21)
SH_t		0.265***	0.246***
		(6.53)	(5.93)
SH_{t-1}		0.113**	0.140***
		(2.19	(2.68)
OS_t		-71.545***	-70.926***
		(-2.85)	(-2.87)
OS_{t-1}		53.911**	48.584**
		(2.41	(2.2)
cons	41.482***	-9.632**	12.18
	(2.6)	(2.28)	(0.99)
N	84	77	74
sargan	77.645	75.967	73.495
sar df	80	68	65

t statistics in parentheses;

* p < 0.1, ** p < 0.05, *** p < 0.01

Table 3-3 presents our full-sample results on the effect of shipping credit spread on shipbuilding market. As shown in column (1), this specification consists of the variable of newbuilding contracts in year $t - 1$ and of shipping credit spread in year $t - 2$. It indicates that the estimate of the impact of shipping credit spread on newbuilding contracts is statistically significant. Specifically, shipping credit spread enters with a negative coefficient, implying that a widening credit spread in year $t-2$ predicts a reduction of newbuilding contracts in year t. Column (2) presents the explanation power of the main fundamental variables, including freight rate, second-hand price of vessel, the ratio of orderbook over fleetsize, and one-year lagged of newbuilding contracts. All the fundamental variables are significant except for the current freight rate. In column (3), the explanatory power of shipping credit spread for newbuilding contracts keeps stable when the fundamental variables are incorporated into the specification. That is, shipping credit spread impacts negatively on the newbuilding contracts, and all variables are statistically significant at the 10% level. FR_t is positively connected with newbuilding contracts, implying that the increase of the contemporary freight rate reflects market profitability and gives an indication of positive expectations in shipping and shipbuilding market. OS_t is negatively related with newbuilding contracts. When OS_t, as a proxy of shipyard capacity, increases, it indicates that more ships will enter into shipping market in a short future, and consequently will reduce the market revenues and the orders for newbuilding. FR_{t-1} has a negative effect on newbuilding contracts. There exists a positive connection between OS_{t-1} and newbuilding contracts. The coefficients of the two control variables illustrate that it takes shipbuilding market around one year to react and respond to the changes of freight rate and OS ratio (shipyard capacity). Our findings are consistent with market overreaction. Shipbuilding market appears to overreact in the current year, and the market reverts in the next year. In particular, when the freight rate increases at time t-1, market participants would immediately change the expectations and react to shipbuilding market at time t-1; but, at time t, those participants might concern carrying overcapacity and lower revenues, and then change to reduce the tonnage of newbuilding contracts.

3.4.1 Shipping credit spread and financial crisis

Referred to Gilchrist, S., and E. Zakrajšek (2012), the financial crisis beginning at year 2007-2008 has damaged the financial markets and real markets over the globe. And then, we consider if there is any difference in shipping credit spread before and after the onset of financial crisis. Thus, our full sample is separated into two subsamples in Table 3-4, one covering the pre-crisis period from year 1996 to 2006 (Panel A), and the other one covering the period from the onset of the crisis from the year 2007 to 2018 (Panel B). The estimated coefficients of shipping credit spread on newbuilding contracts are -0.40 in pre-crisis and -0.006 after the onset of the crisis, respectively, in comparison to the estimation of -0.30 in the full sample. It documents that shipping credit spread does significantly make a more important effect on shipbuilding market before the crisis than that after the onset of the crisis. Namely, global financial crisis makes a certain significant effect on shipping bond market. One possibility is that the credit supply in shipping bond market changes with the financial crisis, which further makes the impacts of shipping credit spread less in the post-crisis than in the pre-crisis. Additionally, it is clear that the estimated coefficient on shipping credit spread of -0.30 in the full sample is consistent with that of -0.40 in the pre-crisis. In other words, the qualitative patterns of shipping credit spread in the pre-crisis are not changed in our full sample, which could still provide a credible estimation.

Table 3-4 Subsample analysis: the period before the crisis, from 1996 to 2006 (Panel A); the period from the onset of the crisis, from 2007 to 2018 (Panel B)

Panel A Pre crisis from 1996 to 2006

	(1) Control variables	(2) All variables
$Contracts_{t-1}$	-0.613	-1.282***
	(-1.56)	(-2.94)
FR_t	0.046	0.069**
	(-1.34)	(-2.09)
FR_{t-1}	-0.005	-0.003
	(-0.11)	(-0.07)
SH_t	0.371***	0.361***
	(4.28)	(4.42)
SH_{t-1}	-0.006	0.067
	(-0.05)	(0.55)
OS_t	-30.966	-3.725
	(-0.71)	(-0.09)
OS_{t-1}	20.392	-41.571
	(0.39)	(-0.75)
CS_{t-2}		-0.040*
		(-1.87)
cons	-11.961*	25.199
	(-1.68)	(1.25)
N	30	27
sargan	31.043	26.512
sar df	21	18

t statistics in parentheses;

* p < 0.1, ** p < 0.05, *** p < 0.01

Panel B Onset of the crisis from 2007 to 2018

	(1) Control variables	(2) All variables
$Contracts_{t-1}$	0.156	0.045
	(0.94)	(0.25)
FR_t	-0.003	-0.025
	(-0.06)	(-0.47)
FR_{t-1}	-0.107***	-0.102***
	(-3.17)	(-2.81)
SH_t	0.357***	0.489***
	(3.75)	(3.73)
SH_{t-1}	0.145*	0.037
	(1.75)	(0.24)
OS_t	-13.436	12.888
	(-0.29)	(-0.24)
OS_{t-1}	-8.825	-29.201
	(-0.21)	(-0.61)
CS_{t-2}		-0.006
		(-0.24)
cons	-3.166	3.481
	(-0.47)	(0.2)
N	44	40
sargan	41.416	43.49
sar df	34	31

t statistics in parentheses;
* p < 0.1, ** p < 0.05, *** p < 0.01

3.4.2 Shipping credit spread and shipping loans

Shipping credit spread is constructed based on the data from shipping bonds, reflecting the credit conditions in shipping bond market. Another traditional and primary way of financing is shipping loans for shipping companies. Shipping loans reflect the credit conditions from the banking system for shipping companies. Thus, it is interesting to consider whether shipping loan market could play the same role with shipping bond market in shipbuilding market.

Table 3-5 Shipping credit spread and shipping loans

	(1) Shipping bond	(2) Shipping loans	(3) Bond & loan	(4) Control variables	(5) All variables
$Contracts_{t-1}$	0.575***	0.578***	0.586***	0.304***	0.266***
	(6.42)	(5.87)	(6.2)	(3.3)	(2.86)
CS_{t-2}	-0.048**		-0.072**		-0.030*
	(-2.00)		(-1.96)		(-1.81)
ΔLO_t		0.053*	0.038		
		(1.8)	(1.31)		
FR_t				0.043	0.043*
				(1.64)	(1.65)
FR_{t-1}				-0.096***	-0.099***
				(-4.02)	(-4.21)
SH_t				0.265***	0.246***
				(6.53)	(5.93)
SH_{t-1}				0.113**	0.140***
				(2.19)	(2.68)
OS_t				-71.545***	-70.926***
				(-2.85)	(-2.87)
OS_{t-1}				53.911**	48.584**
				(2.41)	(2.2)
cons	41.482***	10.534***	54.740**	-9.632**	12.18
	(2.6)	(2.67)	(2.4)	(-2.28)	(0.99)
Standardized effect					
CS_{t-2}	-0.189**		-0.282**		-0.118*
ΔLO_t		0.236*	0.17		
N	84	72	72	77	74
sargan	77.645	65.396	67.216	75.967	73.495
sar df	80	69	68	68	65

t statistics in parentheses;

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The comparison results are showed in Table 3-5. Column (1) presents that the impact of the two-year lagged shipping credit spread on newbuilding contracts is statistically significant. In column (2), the explanatory variable is replaced with the variations of shipping loans, denoted by ΔLO_t. The coefficient of shipping loans is also significant but positive. The signs of the coefficients of shipping loans are consistent with our expectation. Because the increase in shipping loan amount would make more loan supply available in shipping loan market and would be beneficial to shipbuilding market. However, when shipping credit spread and shipping loans are included into the specification in column (3), the coefficient of the two-year lagged shipping credit spread is still significant and gets larger from -0.048 to -0.072, but the coefficient of shipping loans becomes not statistically significant.

In order to compare the impacts of shipping bond market and shipping loans market on newbuilding contracts, standardized estimates of shipping credit spread, and shipping loan size are reported in Table 3-5. As reported in column (1), a one standardized deviation increase in shipping credit spreads (108 basis points) would make a decline in newbuilding contracts of 0.189 standard deviations in two-years later. Similarly, in column (2) a one standardized deviation increase in shipping loans market is related with a step-up in newbuilding contracts of 0.236 standard deviations. When making a comparison by including shipping credit spread and shipping loans into the regression simultaneously in column (3), the coefficient in absolute value on shipping credit spread gets larger to -0.282 and remains significant, while the coefficient of shipping loans decreases to 0.170 and becomes not statistically insignificant. Therefore, the explanatory power of shipping credit spread for shipbuilding market is more robust than that of shipping loans market. Overall, shipping bond market could play a more important role than shipping loan market in shipbuilding market.

3.4.3 Shipping credit spread and forecasting horizons of shipbuilding market

An interesting point is whether the two-year lagged shipping credit spread could affect newbuilding contracts not only in current year t (forecast horizon h0), but also in the following year $t+1$ (forecast horizon h1) and $t+2$ (forecast horizon h2). As shown in Table 3-6, the impacts on newbuilding contracts are to some extentpersistent from year t (horizon h0) to year $t+1$ (horizon h1) from column (1) to column (2). Specifically, the coefficient of shipping credit spread is significant in year $t+1$ (horizon h1), but turns into being insignificant in year $t+2$ (horizon h2). Another interesting point is to estimate the effect of shipping credit spread with a moderate move, based on the effect of ex ante changes of shipping credit spread on shipbuilding market. Referred to López-Salido, Stein and Zakrajšek (2017), we explore what the cumulative impacts of shipping credit spread on newbuilding contracts are when shipping credit spread moves from the 25th to the 75th percentile of its distribution? It is found that the cumulative effect on newbuilding contracts from a credit-spread move is 0.087% in absolute value over the period from t (horizon h0) to $t+1$ (horizon h1), when shipping credit spread increases 92 basis points from the 25th to 75th percentile of its historical distribution. The cumulative effect on shipbuilding market in the second year reaches the highest in absolute magnitude.

Table 3-6 Shipping credit spread and forecasting horizons of newbuilding contracts

	Forecasting horizon		
	(1)	(2)	(3)
	h0	h1	h2
$Contracts_{t-1}$	0.575***	0.435***	0.530***
	(6.42)	(5.16)	(6.98)
CS_{t-2}	-0.048**	-0.047*	0.011
	(-2.00)	(-1.87)	(0.48)
Cumulative effect (%)	-0.044	-0.087	-0.077
N	84	80	76
sargan	77.645	109.737	128.06
sar df	80	76	72

t statistics in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01.
Column “h0”, “h1” and “h2” denote the forecast horizon h=0, 1 and 2, respectively.

When the other six fundamental variables are included into the regression model, the cumulative impact of shipping credit spread on newbuilding contracts becomes -0.032% from -0.087% from year t to t+1 in Table 3-7. Namely, the change from the 25th to 75th percentile in shipping credit spread forecasts a cumulative reduce in newbuilding contracts of 0.032 percentage during the period from t to t+1. In light of those economic magnitudes, shipping bond market is actually a identifiable channel that affects shipbuilding market through shipping credit spread and shipping credit supply.

Table 3-7 Shipping credit spread and forecasting horizons of newbuilding contracts including fundamental variables

	Forecasting horizon		
	(1)	(2)	(3)
	h0	h1	h2
$Contracts_{t-1}$	0.266***	0.031	0.159

	(2.86)	(0.26)	(1.23)
CS_{t-2}	-0.030*	-0.004	0.007
	(-1.81)	(-0.17)	(0.23)
FR_t	0.043*	-0.148***	-0.022
	(1.65)	(-4.36)	(-0.61)
FR_{t-1}	-0.099***	0.091***	0.021
	(-4.21)	(2.95)	(0.63)
SH_t	0.246***	0.395***	0.069
	(5.93)	(7.06)	(1.17)
SH_{t-1}	0.140***	0.016	0.219***
	(2.68)	(0.23)	(3.03)
OS_t	-70.926***	-43.541	-92.807***
	(-2.87)	(-1.35)	(-2.71)
OS_{t-1}	48.584**	3.508	34.458
	(2.2)	(0.12)	(1.13)
Cumulative effect (%)	-0.028	-0.032	-0.026
N	74	70	66
sargan	73.495	71.45	92.599
sar df	65	61	57

t statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Column "h0", "h1" and "h2" denote the forecast horizon h=0, 1 and 2, respectively.

3.4.4 Asymmetric effect of shipping credit spread

All of previous specifications assumed that either increases or decreases in shipping credit spreads have similar effects on shipbuilding market. This subsection relaxes this assumption. It investigates whether there exist any asymmetric effects on shipbuilding contracts in terms of changes in shipping credit spread. In other word, it is examined whether the coefficients on increases of shipping credit spread (CS^+) are consistent with that on decreases of shipping credit spread (CS^-). Table 3-8 shows the results of an asymmetric response of shipbuilding market to changes in shipping credit spread. In column (1), during the whole period from 1996 to 2018, the estimated coefficient of –0.048 on increases of shipping credit spread is slightly greater in absolute values than the coefficient of –0.014 on decreases of shipping credit spread. The asymmetric response of shipbuilding market to increases in shipping credit spread are statistically significant at 10% level. Those findings suggest that when the capital market is overheating, shipping credit market will tighten and a shrinking in credit supply would make a more powerful effect on shipbuilding market than a credit supply expansion; and that the impact of a contracting in shipping credit supply is statistically remarkable from that of a credit easing. Column (2) and (3) present the results for the periods before the crisis and onset of the crisis. The coefficients correlated with the increases of shipping credit spread are also greater in absolute values than those for the decreases of shipping credit spread, but neither the coefficients for increases of shipping credit spread nor those for decreases of shipping credit spread are statistically significant.

Table 3-8 Asymmetric effect of changes in shipping credit spread

	(1)	(2)	(3)
	1996-2018	1996-2006	2006-2018
$Contracts_{t-1}$	0.260***	-1.173***	0.164
	(2.73)	(-2.81)	(0.81)
FR_t	0.042	0.052	0.007
	(1.59)	(1.61)	(0.1)
FR_{t-1}	-0.106***	0.007	-0.147***
	(-4.40)	(0.18)	(-2.75)
CS^{+}_{t-2}	-0.048*	-0.058	-0.03
	(-1.77)	(-1.37)	(-0.95)
CS^{-}_{t-2}	-0.014	-0.03	0.017
	(-0.49)	(-1.01)	(0.36)
SH_t	0.235***	0.435***	0.573***
	(5.6)	(3.86)	(3.51)
SH_{t-1}	0.177***	-0.027	-0.075
	(3.15)	(-0.17)	(-0.41)
OS_t	-74.463***	-40.761	24.174
	(-2.99)	(-0.91)	(0.41)
OS_{t-1}	54.049**	21.364	-28.824
	(2.42)	(0.36)	(-0.56)
cons	-7.499	-5.513	0.162
	(-1.55)	(-0.64)	(0.02)
N	71	24	36
sargan	70.167	22.647	41.617
sar df	61	14	26

t statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The coefficient on increases of shipping credit spread is denoted as CS^{+}_{t-2}; the coefficient on decreases of shipping credit spread is denoted by CS^{-}_{t-2}.

3.5 Discussion

The shipping credit spread we constructed significantly impacts on the fluctuations in shipbuilding market. The reasons behind this are as follows: firstly, shipbuilding market is highly capital intensive, relying on various financing sources; as one important source of financing (Stopford, 2009), shipping bond market has assumed an increasing role particularly in the periods of the bank-loan shortage (Kavussanos and Tsouknidis, 2014). Specifically, the buoyant shipping credit spread in year t-2 has a negative effect on shipbuilding market in year t. From the perspectives of shipowners, the higher shipping credit spread makes an increase in financing costs, which induces the deduct of shipowners' ordering newbuilding contracts. From the perspective of market-level, the variations of shipping credit spread could reflect the changes in the credit supply by financial intermediaries. When credit risk is aggressively priced and expected returns to bearing the risk are driven down, financial intermediaries would reduce the supply of credit, and credit spreads subsequently widens, as a consequence of more difficult financing and then less spending and production for corporates (Gilchrist and Zakrajšek, 2012). Similarly, in shipping industry, the higher volatility and the worsening credit conditions make financial institutions reduce their credit supply, which results in the difficulty in bond financing and the decrease of newbuilding contracts. Overall, movements in shipping credit spread mirror changes in the effective credit supply provided by financial institutions, which is the mechanism of the predictive content of shipping credit spread for shipping activities. Fluctuations in shipping credit spread carry crucial information and signals regarding the development and risk of shipping industry.

3.6 Conclusions

This chapter investigates what a role of shipping credit spread plays in shipbuilding market. Firstly, shipping credit spread is constructed as an indicator of shipping bond market. And then the econometric regressions are conducted to examine the role of shipping credit spread in shipbuilding market. It is found that an increase of shipping credit spread in year t-2 has a negative impact on shipbuilding market in year t. Namely, it implies that in reality shipbuilding market would have two-year lagged reaction in response to changes in shipping bond market. In addition, this study identifies that the global financial crisis would have an effect on the role of shipping credit spread in shipbuilding market. Fourthly, shipping credit spread could affect newbuilding contracts not only in current year but also the following year. More importantly, shipping bond market imposes the more important effect on the shipbuilding market than shipping loans market. Last but not least, there exists an asymmetric effect of shipping credit spread on shipbuilding market. The mechanism behind those findings is that an increase of shipping credit spread makes an increase in financing costs, which facilitates a decline of ship ordering and shipbuilding contracts. We document that shipping bond market is actually a identifiable channel of making economic/financial effects on shipbuilding market via shipping credit spread and shipping credit supply.

The findings of this chapter have important implications for shipowners, shipping companies and market investorsin the shipping industry to make expectations and decision in term of the credit-market condition. Specifically, when shipping credit spread increases, it suggests that those ship investors need to be more conservative to purchase vessels by issuing bonds since they have to make higher interest and repayment and they may have no sufficient cash flow to fulfil the obligations in the period of shipping market turmoil. For financial institutions, they should pay more attention to manage the risk and the default of relevant shipping bonds. For shipping companies, when the drop of shipping credit spread would increase shipbuilding contracts, shipping companies should make the corresponding expectations of carrying overcapacity of shipping industry in the short future, and then make further decisions to hedge operational risks.

Chapter 4

The Sea Transportation of International Trade Cargo: An Empirical Analysis

4.1 Introduction

Ocean transportation plays the key role of global multimodal transport in both inbound and outbound supply chains, and it is thus important to international business studies. Seaborne transportation that is able to meet the evolving requirements can ensure that its international business system remains competitive and enables the comparative and competitive advantages of the system's hinterlands to be attained. The role of maritime transportation is therefore essential since maritime transportation systems and operations are important and indispensable for the effective and efficient management of flows of products in the supply chains.

Shipping, as a means of earning or conserving foreign exchange, is an important consideration of seaborne freight transportation service. The output of shipping transportation is measured in two quantities: firstly, in terms of the values of cargo being moved per time period; and secondly, in terms of the distance being sailed per time period. For instance, in the international trade, Yip (2012) and Valentine, Benamara, Hoffmann (2013) modeled the seaborne freight transportation in terms of the values of international trade cargo transported. Especially, the values are actually used as a proxy variable for this services and are tightly associated with the interests of trading countries. From this perspective of national economy, shipping output is often measured in terms of costs and revenues (defined in US dollars or local currency where it is incurred).

However, from the perspective of transportation service for international trade cargo, the economic output is actually a flow of cargo moved over the distance. The single dimension could not explain the costs of this transportation service enough. Average distance travelled is thus a proxy for route structure. For instance, a trade war will shift some direct trades to transhipment trades, and route structure will increase ton-miles output. Also, various cargoes and different tonnages closely make an effect on the variations of ton-miles output. Hence, this study adopts the ton-mile approach to measure sea transportation of international trade cargo. The ton-mile metric is the product of cargo tonnage and distance travelled per time period.

In the international business literature, the determinants of transportation activities are found to be important behind the business decision-making (Doh, Bunyaratave and Hahn, 2009; Pearce, 2017). The contemporary phenomena of globalization can be modelled in the perspective of value chains (Kano, 2018) and human networks (Madhavan and Iriyama, 2009). Therefore, we attempt to model seaborne freight transportation service for global and international trade cargo.

Since 2016, UNCTAD (the United Nations Conference on Trade and Development) of the United Nations has collected the data "seaborne ton-miles of transportation service". The data for such an investigation has not been available in the past. Therefore, this study should be the first attempt in the academic and industrial literature that investigates determinants of seaborne freight transportation service, to use a specific 'new' measurement of this service, UNCTAD's "seaborne ton-miles of transportation service". Also, we should be the first to utilize this new dataset of UNCTAD.

The reminder of this chapter is organized as follows. Section 4.2 presents the importance of seaborne transportation services in ton-miles of international trade cargo. Section 4.3 estimates the effect of trade agreements and major countries on the sea transportation of international trade cargo. Section 4.4 presents the equation estimation results. Section 4.5 sets forth conclusions with the implications.

4.2 New measure of sea transportation of international trade cargo

A physical product when produced can be seen and touched, but a service cannot when it is provided. Freight transportation provides a service in transporting cargo from one location to another and thus is measured as a service. The ton-mile is the most commonly used measure of seaborne freight transportation service. For deeper analysis, this measure in ton-miles is far from satisfactory in that it treats all tons of cargo as if it were the same. For example, moving 100 tons of dry bulk a given distance is treated the same as moving 100 tons of liquid bulk the same distance. Obviously these two seaborne transportation services are quite different. As discussed, if such single aggregate measure of transportation output is used, they may bias the estimates of the production technology of the transportation sector in industry. Furthermore, there exist a wide range of commodities required to be transported by different types of ships. It could not be completed to measure each type of sea transportation in ton-miles for the corresponding commodities. Therefore, based on the available data, this research categorizes seaborne transportation service of international trade cargo into four subsectors, dry bulk, liquid bulk, and other cargo, respectively.

Based on the existing literature, there are some factors that make a difference in the sea transportation of international trade cargo, for exporting to the same import markets or for importing from the same export markets. In other words, there exists the essential difference in the sea transportation of international trade cargo from which country the cargo is exported and to which country the cargo is imported. Tinbergen (1962) and Poyhonen (1963) stated that countries with a large economic scale tend to trade more with those countries having a similar economic size, and trade less with those partners having a remote geographical distance. The larger volume of trade between countries increases the two-sided sea transportation. Hence, those variables, firmly connected with biliteral economic scale, are the important factors in the sea transportation of international trade cargo. Figure 4-1 draws the graph regarding the growth of world GDP, world trade, and world seaborne transportation during the period between 1991 and 2021. It displays that the variation of the world seaborne transportation is tightly connected with the growth of the world GDP and the world trade.

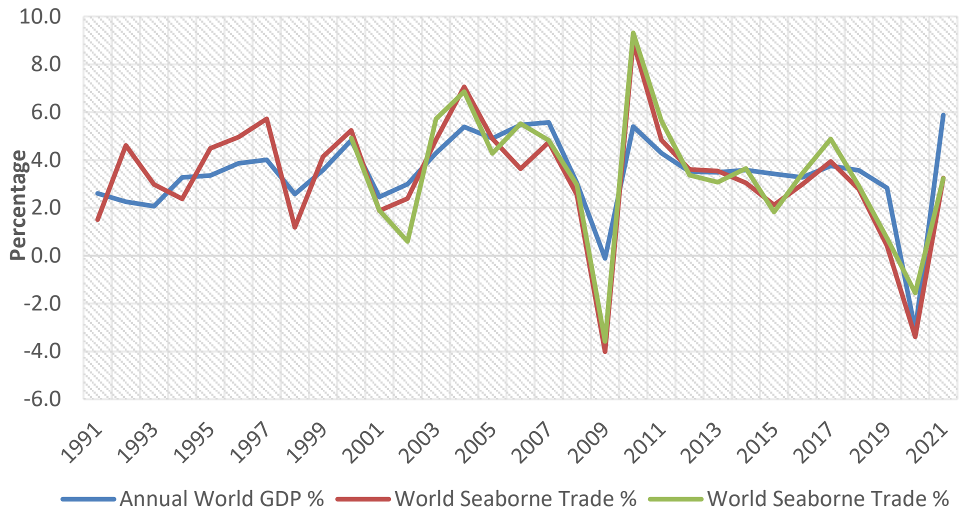


Figure 4-1 The growth of world GDP, world trade volume, and world seaborne transportation volume during the period between 1991 and 2021

Furthermore, Baier, Kerr and Yotov (2018) pointed out that whether countries are the members of free trade agreements may tightly affect the link between trading partners. There are three notable free trade agreements, WTO, NAFTA and CAFTA respectively. WTO is the World Trade Organization; NAFTA is the North American Free Trade Agreement; CAFTA is the Central American Free Trade Agreement. In addition, by 20202 the top 10 of world exporting nations account for 52% of global goods exports. The major exporting and importing countries are the primary elements of the sea transportation of international trade cargo. Yet, there is insufficient research that examines the impact of trade agreement and major exporting and importing countries on seaborne trade and seaborne freight transportation with regard to the ton-mile measurement. Thus, this study will address this issue to fill the gap in the literature. Moreover, it contributes to the trade literature from the side of transportation costs and transportation economics.

4.3 Econometric modelling

The determinants of transportation activities are important to understand maritime economics (Talley, Yip and Jin, 2012; Yip and Talley, 2015; Talley, 2019; Talley and Ng, 2020). Based upon our understanding of the seaborne freight transportation, the following variables can be deduced from the data and used in the estimation of the sea transportation of international trade cargo.

The dependent variable for the "the sea transportation of international trade cargo" is measured by "seaborne ton-miles of cargo transportation". Given that the data include separate information on seaborne freight transportation service of dry bulk, liquid bulk, and other cargo, separate seaborne transportation of international trade cargo could be estimated for dry bulk, liquid bulk and other cargoes, respectively, using the following dependent variables in the estimations of the four regressions: a) seaborne dry bulk ton-miles, b) seaborne liquid bulk ton-miles, c) seaborne other cargoes ton-miles, and d) seaborne all cargoes ton-miles.

Since the trading countries are specified in the data, these data, in turn, are used to create major ex-import country dummy variables to distinguish whether a country is one of the major export or import countries. Tinbergen (1962) and Poyhonen (1963) argued that countries with a large economic scale tend to trade more. Major exporters of cargo are Brazil, US, Canada, and Mexico; and major importers are China, Canada, and Mexico. Therefore, these countries are indexed as dummy variables to explore the impact of the major exporting and importing countries on sea transportation of international trade cargo. Also, these data are used to create dummy variables to denote whether a country is a member of a certain international trading group such as WTO, NAFTA and CAFTA groups and to investigate the effects of these memberships on sea transportation of international trade cargo. We hypothesize that membership of free trade agreements (WTO, NAFTA and CAFTA), and the dummies of a major exporting or importing country, are the key determinants of sea transportation of international trade cargo.

The GDP and GDP per capita (GDPPC) of exporting and importing countries are the roots of international trade and sea transportation. This research takes the three GDP-related fundamental variables and their geographical distance, as control variables in the model to analyze the sea transportation of international trade cargo. GDP_{ijt} is the sum of real GDPs of exporting and importing countries, reflecting the economy scale of trading partners. SIM_{ijt} presents the similarity of economy scale of exporting and importing countries (Helpman, 1987). Its value is positive; and when the value become larger, the economy scale of the two trading partners is more similar, implying that the trade between countries is higher. RFE_{ijt} is the absolute difference in relative factor endowments of exporting and importing countries, which is negatively linked with the trade between the two countries (Linder, 1964; Bergstand, 1990).

Based on the New Trade Theory (Krugman, 1980; Helpman and Krugman, 1985), the international trade between trading partners is affected by their scale economy. The gravity models and equations have been applied broadly in international trade literatures and transportation studies. For instance, Isard (1954) employed the gravity model to predict the bilateral trade flows between paired countries. The basic gravity model is displayed by the following equation:

$$Y_{ij} = A * \frac{X_i * X_j}{D_{ij}}$$

Where

Y_{ij}: international trade between trading partners;

X_i: economic size of country i

X_j: economic size of country j

D_{ij}: distance between country i and country j;

In this study, the extended gravity model is developed to investigate the effect of trade agreement and major exporting and importing countries on the sea transportation of international trade cargo (Y_{ijt}) :

$$Y_{ijt} = \alpha + \beta_1 WTO_{it}^{ex} + \beta_2 NAFTA_{it}^{ex} + \beta_3 CAFTA_{it}^{ex} + \beta_4 WTO_{jt}^{im} + \beta_5 NAFTA_{jt}^{im} + \beta_6 CAFTA_{jt}^{im} + \beta_7 Brazil_{it}^{ex} + \beta_8 US_{it}^{ex} + \beta_9 Canada_{it}^{ex} + \beta_{10} Mexico_{it}^{ex} + \beta_{11} China_{jt}^{im} + \beta_{12} Canada_{jt}^{im} + \beta_{13} Mexico_{jt}^{im} + \beta_{14} GDP_{ijt} + \beta_{15} SIM_{ijt} + \beta_{16} RFE_{ijt} + \beta_{17} Distance_{ij} + \varepsilon_{ijt}, \ (i \neq j) \quad (4\text{-}1)$$

where

i, the exporter index;

j, the importer index;

t, the year index, representing the time when seaborne transportation takes place;

Y_{ijt}, the ton-miles of sea transportation of international trade cargo;

α, the constant, unobserved or fixed effects which do not change over time across locations;

β_i, all the coefficients of explanatory variables to be estimated ($i = 1, \ldots, 17$).

WTO_{it}^{ex}, the dummy variable (=1 if the i-th exporter is a member of WTO; =0 otherwise);

$NAFTA_{it}^{ex}$, the dummy variable (=1 if the i-th exporter is a member of NATFA; =0 otherwise);

$CAFTA_{it}^{ex}$, the dummy variable (=1 if the i-th exporter is a member of CATFA; =0 otherwise);

WTO_{jt}^{im}, the dummy variable (=1 if the j-th importer is a member of WTO; =0 otherwise);

$NAFTA_{jt}^{im}$, the dummy variable (=1 if the j-th importer is a member of NATFA; =0 otherwise);

$CAFTA_{jt}^{im}$, the dummy variable (=1 if the j-th importer is a member of CATFA; =0 otherwise);

$Brazil_{it}^{ex}$, the dummy variable (=1 if the i-th exporter is Brazil; =0 otherwise);

US_{it}^{ex}, the dummy variable (=1 if the i-th exporter is the United States; =0 otherwise);

$Canada_{it}^{ex}$, the dummy variable (=1 if the i-th exporter is Canada; =0 otherwise);

$Mexico_{it}^{ex}$, the dummy variable (=1 if the i-th exporter is Mexico; =0 otherwise);

$China_{jt}^{im}$, the dummy variable (=1 if the j-th importer is China; =0 otherwise);

$Canada_{jt}^{im}$, the dummy variable (=1 if the j-th importer is Canada; =0 otherwise);

$Mexico_{jt}^{im}$, the dummy variable (=1 if the j-th importer is Mexico; =0 otherwise);

$Distance_{ij}$, the geographical distance between trading partners;

GDP_{ijt}, is the economy scale of trading partners; GDP_{it}^{ex} is the economy size of the exporter i; GDP_{jt}^{im} is the economy size of the importer j; $GDP_{ijt} = GDP_{it}^{ex} + GDP_{jt}^{im}$;

SIM_{ijt}, presents the similarity of economy scale of trading partners; $SIM_{ijt} = 1 - \left(\frac{GDP_{it}^{ex}}{GDP_{it}^{ex}+GDP_{jt}^{im}}\right)^2 - \left(\frac{GDP_{it}^{im}}{GDP_{it}^{ex}+GDP_{jt}^{im}}\right)^2$;

RFE_{ijt}, is the absolute difference in relative factor endowments of trading partners; $RFE_{ijt} = \left|\ln(GDPPC_{it}^{ex}) - \ln(GDPPC_{jt}^{im})\right|$.

Free trade agreements play an important role in enhancing trade liberalization and promoting trade (Baier, Kerr, and Yotov, 2018; Baier and Bergstrands, 2007). Thus, it is expected that free trade agreements are positively associated with sea transportation. Tinbergen (1962) and Poyhonen (1963) stated that countries with a large economic scale tend to trade more. The dummy variables of a major exporting or importing country are expected to positively connect with sea transportation. WTO (World Trade Organization) membership is critical to the growth of Asian countries' exports because all quota restrictions on cargoes among WTO members were scheduled to be removed completely by 2005, as set out in the WTO's Agreement. It is anticipated that the sign of the variable WTO should be positive. The dummy variables NAFTA (the North American Free Trade Agreement) and CAFTA (The Central American Free Trade Agreement) are also expected to capture the positive impact on sea transportation.

4.4 Econometric results

This study estimates the effect of trade agreements and main exporter and importer countries on the sea transportation of international trade cargo in terms of new measurement 'ton-miles', with the data (Table 4-1) collected from UNCTAD. Seaborne ton-miles of transportation service between trading partners source from UNCTAD (the United Nations Conference on Trade and Development) in 2016, and the data covers almost all trading partners over the world. The data of GDP, GDP-relative, trade agreements, and major exporting and importing countries comes from World Bank. The regression analysis is conducted by using an econometric and statistical software, STATA. In this research, the cross-sectional data in 2016 is analyzed to estimate the regression coefficients with the maximum likelihood (ML) estimation. The assumption of OLS that variables are continuous and random is not held, because most of explanatory variables are dummy variables. It is considered that the ordinary least squares (OLS) is not the best approach to estimation. The maximum likelihood (ML) method is an alternative to ordinary least squares (OLS) and provides a more general approach to the problem of finding regression estimators of unknown population parameters.

Table 4-1 Variable definitions

Variable	Measurement
	Dependent variable
Y	the value of seaborne freight transportation service [ton-miles]
	Explanatory variables
	Type of trade agreement
WTO^{ex}	1 if the exporting country is a member of WTO (formerly known as GATT)
$NAFTA^{ex}$	1 if the exporting country is a member of NAFTA
$CAFTA^{ex}$	1 if the exporting country is a member of CAFTA
WTO^{im}	1 if the importing country is a member of WTO (formerly known as GATT)
$NAFTi^{Im}$	1 if the importing country is a member of NAFTA
$CAFTA^{im}$	1 if the importing country is a member of CAFTA
	Major exporting and importing countries
$Brazil^{ex}$	1 if the exporting country is Brazil
US^{ex}	1 if the exporting country is the United States
$Canada^{ex}$	1 if the exporting country is Canada
$Mexico^{ex}$	1 if the exporting country is Mexico
$China^{im}$	1 if the importing country is China
$Canada^{im}$	1 if the importing country is Canada
$Mexico^{im}$	1 if the importing country is Mexico
i	the exporter index
j	the importer index
t	the year index, representing the time when seaborne transportation takes place

Table 4-2 The effect of only major exporting and importing countries on the sea transportation of international trade cargo

	(1) Dry bulk	(2) Liquid bulk	(3) Other cargo	(4) All cargo
GDP2016	1.881***	1.004***	3.151***	3.031***
	(38.18)	(16.78)	(94.67)	(93.44)
SIM2016	8.628***	7.718***	12.67***	12.22***
	(20.76)	(16.15)	(42.24)	(41.52)
RFE2016	-0.492***	-0.166*	-0.322***	-0.345***
	(-8.16)	(-2.26)	(-7.20)	(-7.88)
$Brazil^{ex}$	1.623***	1.225*	1.594***	1.651***
	(3.30)	(2.33)	(3.45)	(3.61)

US^{ex}	-8.941*	.	-4.061*	-4.504**
	(-2.43)	.	(-2.25)	(-2.67)
$China^{im}$	-1.229***	-2.601***	-3.630***	-3.113***
	(-3.65)	(-6.57)	(-12.12)	(-10.52)
Distance	-0.000158***	-0.0000960***	-0.000229***	-0.000229***
	(-13.20)	(-6.75)	(-25.45)	(-26.02)
cons	-26.95***	-8.058***	-60.21***	-56.06***
	(-19.92)	(-4.88)	(-66.90)	(-63.95)
sigma				
GDP2016	-0.0242			
	(-0.89)			
cons	5.828***	4.905***	5.094***	5.047***
	(7.86)	(92.18)	(151.09)	(152.60)
N	6672	4249	11414	11643

Note: t statistics in parentheses; * p<0.05, ** p<0.01, *** p<0.001.
US^{ex} omitted because of collinearity; $Mexico^{ex}$ omitted because of collinearity; $China^{im}$ omitted because of collinearity; $Canada^{im}$ omitted because of collinearity; $Mexico^{im}$ omitted because of collinearity. Chow test displays that the coefficients of all dummy variables are jointly significant. The likelihood test shows that there exists the heteroscedasticity only in the dry bulk sector.

Table 4-2 estimates the effect of only major exporting and importing countries variables on sea transportation of international trade cargo for each sector. In all sectors, the control variables, GDP2016 and SIM2016, are positively connected with sea transportation; and RFE2016 are negatively associated with the sea transportation of international trade cargo; the geographical distance has a persistent negative association with sea transportation in ton-miles. Longer distance between trading partners, as an indicator of transportation costs, hinder bilateral trade. Tinbergen (1962) and Poyhonen (1963) stated that countries with a large economic scale tend to trade more with those countries having a similar economic size, and trade less with those partners having a remote geographical distance. This finding is in accordance with the existing literature. As shown in Table 4-2, the variables of major export and import countries, $Canada^{ex}$, $Mexico^{ex}$, $Canada^{im}$, and $Mexico^{im}$, are omitted due to the collinearity. To the best of our knowledge, Canada and Mexico are of geographical proximity to US, and their trading patterns are similar. Therefore, those four variables are dropped due to perfect collinearity. As the major export countries, Brazil has a positive effect on the sea transportation of international trade for dry bulk, liquid bulk, other cargo, and all cargo sector, which is in line with our expectation. But the variable US^{ex} negatively affects the sea transportation of international trade cargo for dry bulk, other cargo, and all cargo sectors, as is against our expectation. It is possibly resulted in by insufficient explanatory variables in the specification, which is proved through our further estimations. The variable $China^{im}$ is negatively connected with the sea transportation of international trade cargo for dry bulk, liquid bulk, other cargo, and all cargo sectors.

Table 4-3 The effect of only trade agreements on the sea transportation of international trade cargo

	(1) Dry bulk	(2) Liquid bulk	(3) Other cargo	(4) All cargo
GDP2016	1.805***	0.899***	2.980***	2.876***
	(38.71)	(15.43)	(94.48)	(93.77)
SIM2016	8.574***	7.752***	12.46***	11.98***
	(20.69)	(16.12)	(41.59)	(40.86)
RFE2016	-0.490***	-0.123	-0.286***	-0.320***
	(-8.17)	(-1.67)	(-6.46)	(-7.39)
WTO^{ex}	1.631***	0.570	2.565***	2.579***
	(6.53)	(1.67)	(16.05)	(16.69)
$NAFTA^{ex}$	-9.178*	-3.089	-6.565***	-7.119***
	(-2.49)	(-0.63)	(-5.01)	(-5.68)
$CAFTA^{ex}$	-1.008*	1.706**	-0.662*	-0.819**
	(-2.43)	(3.13)	(-2.47)	(-3.11)
WTO^{im}	-0.149	-0.0899	0.173	0.259
	(-0.71)	(-0.34)	(1.18)	(1.81)
$NAFTA^{im}$	-5.744**	-2.910	-4.737***	-5.286***
	(-3.16)	(-1.67)	(-5.26)	(-5.95)
$CAFTA^{im}$	-0.330	-0.210	-0.316	-0.375
	(-0.83)	(-0.44)	(-1.14)	(-1.40)
Distance	-0.000160***	-0.0000983***	-0.000231***	-0.000232***
	(-13.43)	(-6.88)	(-25.88)	(-26.46)
cons	-26.23***	-5.792***	-58.15***	-54.48***
	(-20.31)	(-3.61)	(-67.99)	(-65.57)
sigma				
GDP2016	-0.0316			
	(-1.15)			
cons	6.017***	4.924***	5.063***	5.002***
	(8.06)	(92.18)	(151.09)	(152.60)
N	6672	4249	11414	11643

Note: t statistics in parentheses; * p<0.05, ** p<0.01, *** p<0.001.
Chow test displays that the coefficients of all dummy variables are jointly significant. The likelihood test shows that there exists the heteroscedasticity only in the dry bulk sector.

Table 4-3 shows the effect of only trade agreements on the sea transportation of international trade cargo. For four cargo sectors, the geographical distance is still negatively related with the sea transportation in dry bulk, liquid bulk, other cargo, and all cargo. As exporters, being a membership of WTO, has a beneficial impact on the sea transportation of international trade cargo for four cargo sectors. WTO^{im} is not statistically significant in our regression. Contrarily, the variables, NAFTA and CAFTA, negatively affect the sea transportation of international trade cargo when an exporter or importer country is being a member of NAFTA and CAFTA for almost four cargo sectors.

Table 4-4 The effect of only export countries on the sea transportation of international trade cargo

	(1) Dry bulk	(2) Liquid bulk	(3) Other cargo	(4) All cargo
GDP2016	1.795***	0.891***	2.977***	2.876***
	(38.57)	(15.41)	(94.61)	(93.96)
SIM2016	8.646***	7.820***	12.57***	12.10***
	(20.87)	(16.31)	(42.07)	(41.37)
RFE2016	-0.474***	-0.105	-0.269***	-0.302***
	(-7.90)	(-1.43)	(-6.07)	(-6.98)
WTO^{ex}	1.601***	0.543	2.527***	2.537***
	(6.41)	(1.60)	(15.81)	(16.41)
$NAFTA^{ex}$	-9.135*	-3.078	-9.144***	-10.02***
	(-2.48)	(-0.62)	(-4.77)	(-5.29)
$CAFTA^{ex}$	-0.997*	1.704**	-0.627*	-0.780**
	(-2.40)	(3.15)	(-2.34)	(-2.96)
$Brazil^{ex}$	1.620***	1.405**	1.664***	1.667***
	(3.31)	(2.66)	(3.63)	(3.68)
US^{ex}	.	.	5.041	5.381*
	.	.	(1.92)	(2.13)
Distance	-0.000161***	-0.0000995***	-0.000234***	-0.000235***
	(-13.48)	(-6.97)	(-26.23)	(-26.83)
cons	-26.12***	-5.703***	-57.94***	-54.27***
	(-20.23)	(-3.56)	(-67.61)	(-65.17)
sigma				
GDP2016	-0.0319			
	(-1.17)			
cons	6.026***	4.922***	5.066***	5.007***
	(8.09)	(92.18)	(151.09)	(152.60)
N	6672	4249	11414	11643

Note: t statistics in parentheses; * p<0.05, ** p<0.01, *** p<0.001.
US^{ex} in dry bulk and liquid bulk omitted because of collinearity; $Canada^{ex}$ omitted because of collinearity; $Mexico^{ex}$ omitted because of collinearity. Chow test displays that the coefficients of all dummy variables are jointly significant. The likelihood test shows that there exists the heteroscedasticity only in the dry bulk sector.

Table 4-4 displays the estimated effect of considering only '*export*' country variables on the sea transportation of international trade cargo. All the control variables still hold. $Brazil^{ex}$ still keep positive associations with the sea transportation in all four sectors. The variable US^{ex} has a positive impact on the sea transportation for other cargo and all cargo when only taking the 'export' country variables into account. The coefficients of WTO^{ex}, $NAFTA^{ex}$ and $CAFTA^{ex}$ are similar to that in the previous specifications, and all are statistically significant except for $NAFTA^{ex}$ in liquid sector.

Table 4-5 The effect of only import countries on the sea transportation of international trade cargo

	(1) Dry bulk	(2) Liquid bulk	(3) Other cargo	(4) All cargo
GDP2016	1.899***	1.012***	3.160***	3.039***
	(38.61)	(16.87)	(95.07)	(93.83)
SIM2016	8.585***	7.646***	12.59***	12.14***
	(20.65)	(15.95)	(41.87)	(41.15)
RFE2016	-0.507***	-0.183*	-0.339***	-0.362***
	(-8.40)	(-2.49)	(-7.58)	(-8.28)
WTO^{im}	-0.168	-0.0240	0.155	0.221
	(-0.80)	(-0.09)	(1.06)	(1.53)
$NAFTA^{im}$	-5.714**	-3.096	-4.744***	-5.235***
	(-3.13)	(-1.78)	(-5.24)	(-5.84)
$CAFTA^{im}$	-0.328	-0.123	-0.290	-0.360
	(-0.82)	(-0.26)	(-1.05)	(-1.33)
$China^{im}$	-1.303***	-2.659***	-3.732***	-3.225***
	(-3.87)	(-6.72)	(-12.47)	(-10.91)
Distance	-0.000158***	-0.0000949***	-0.000226***	-0.000227***
	(-13.19)	(-6.66)	(-25.18)	(-25.76)
cons	-27.23***	-8.209***	-60.52***	-56.40***
	(-20.12)	(-4.97)	(-67.43)	(-64.54)
sigma				
GDP2016	-0.0239			
	(-0.88)			
cons	5.822***	4.906***	5.091***	5.043***
	(7.83)	(92.18)	(151.09)	(152.60)
N	6672	4249	11414	11643

Note: t statistics in parentheses; * p<0.05, ** p<0.01, *** p<0.001. $Canada^{im}$ omitted because of collinearity; $Mexico^{im}$ omitted because of collinearity. The likelihood test shows that there exists the heteroscedasticity only in the dry bulk sector. Chow test displays that the coefficients of all dummy variables are jointly significant.

Table 4-5 presents the effect of considering only '*import*' country variables on the sea transportation of international trade cargo. All the results of control variables are consistent with the previous results. The relationship between $China^{im}$ and sea transportation is kept negative. The memberships of NAFTA and CAFTA of importers are still negatively connected with sea freight transportation. However, the effects of the variable, WTO^{im} , is not statistically significant in all four sectors. It illustrates that the impact of the membership of the free trade agreements, on sea transportation is not remarkable when only taking an insufficient consideration of 'import' countries.

Table 4-6 The effect of trade agreements and major exporting and importing countries on the sea transportation of international trade cargo (MLE)

	(1) Dry bulk	(2) Liquid bulk	(3) Other cargo	(4) All cargo
GDP2016	1.848***	1.011***	3.094***	2.970***
	(37.35)	(16.62)	(93.12)	(91.85)
SIM2016	8.598***	7.685***	12.41***	11.94***
	(20.77)	(16.07)	(41.69)	(40.94)
RFE2016	-0.501***	-0.158*	-0.330***	-0.355***
	(-8.31)	(-2.15)	(-7.44)	(-8.20)
WTO^{ex}	1.577***	0.443	2.459***	2.490***
	(6.32)	(1.31)	(15.46)	(16.18)
$NAFTA^{ex}$	-9.189*	-3.016	-9.435***	-10.29***
	(-2.49)	(-0.62)	(-4.96)	(-5.47)
$CAFTA^{ex}$	-0.934*	1.838***	-0.569*	-0.740**
	(-2.25)	(3.40)	(-2.14)	(-2.82)
WTO^{im}	-0.109	-0.0367	0.244	0.319*
	(-0.52)	(-0.14)	(1.69)	(2.24)
$NAFTA^{im}$	-6.009***	-3.044	-5.069***	-5.579***
	(-3.31)	(-1.75)	(-5.67)	(-6.31)
$CAFTA^{im}$	-0.379	-0.312	-0.378	-0.426
	(-0.95)	(-0.66)	(-1.38)	(-1.60)
$Brazil^{ex}$	1.573**	1.230*	1.473**	1.529***
	(3.22)	(2.34)	(3.23)	(3.39)
US^{ex}	.	.	5.014	5.379*
	.	.	(1.93)	(2.14)
$China^{im}$	-1.124***	-2.627***	-3.471***	-2.962***
	(-3.37)	(-6.63)	(-11.71)	(-10.13)
Distance	-0.000158***	-0.0000942***	-0.000227***	-0.000227***
	(-13.25)	(-6.62)	(-25.48)	(-26.10)
cons	-27.38***	-8.696***	-61.04***	-56.86***
	(-20.10)	(-5.22)	(-68.28)	(-65.42)
sigma				
GDP2016	-0.0414			
	(-1.51)			
cons	6.276***	4.895***	5.029***	4.976***
	(8.38)	(92.18)	(151.09)	(152.60)
N	6672	4249	11414	11643

Note: t statistics in parentheses; * p<0.05, ** p<0.01, *** p<0.001.
US^{ex} in dry bulk and liquid bulk sector omitted because of collinearity; $Canada^{ex}$, $Mexico^{ex}$, $Canada^{im}$, and $Mexico^{im}$ omitted because of collinearity. Chow test displays that the coefficients of all dummy variables are jointly significant. The likelihood test shows that there exists the heteroscedasticity only in the dry bulk sector.

Table 4-6 exhibits that the effect of trade agreements and major exporting and importing countries on the sea transportation of international trade cargo for four sectors. In other words, the specification includes all the newly added explanatory variables and control variables. When taking all factors into account, WTO^{ex} indicates that joining WTO as an exporter positively impacts on sea transportation in four sectors; and the influence of WTO^{im} stays positive but turns to be significant at least at a 10% difference level in all cargo sector. WTO^{im} indicate that joining WTO is beneficial to sea transportation activities between trading partners, because WTO is a global trade organization to reduce trade barrels and make trade liberalization between trading partners. The negative coefficients of WTO^{im} in dry bulk cargo and liquid cargo sector are not statistically significant. In liquid sector, the positive relation between CAFTA and sea transportation illustrates that liquid bulk is rarely carried by load transport and the membership of CAFTA enables the increase of sea transportation. Conversely, the coefficients of the memberships of NAFTA and CAFTA keep negative against our expectations, and are statistically important except for $CAFTA^{im}$ in four sectors. To the best of our knowledge, NAFTA and CAFTA are recognized as regional trade agreements, having restricted members. Thus, the effects of the two trade agreements are limited to member countries only, particularly depending more on both trading partners than only one of them. When only one of trading partners is the membership of NAFTA or CAFTA, it would be not helpful to sea transportation between trade partners.

As the major exporting countries, Brazil and US has a positive and significant effect on the sea transportation. In Table 4-2, the coefficient of US^{ex} is significantly negative, which is against our expectation. One possibility is that only country dummies added into the model specification result into the inefficient estimation. And then, when more sufficient variables are added into the model specifications, the negative coefficients of US^{ex} are the positive signs in Table 4-4, 4-6, 4-7 and 4-8, which is in line with the expected relationship.

The variable $China^{im}$ is negatively connected with the sea transportation, which is against our expectation. Based on the New Trade Theory (Krugman, 1980; Helpman and Krugman, 1985), there exists scale economy effect between trading partners from the view of economics. Namely, the economy of scale is a critical factor in determining international patterns of trade, and countries with a lager economy size tend to trade more (Tinbergen, 1962; Poyhonen, 1963). However, China, as a major importing country, has a negative connection with sea transportation, which is in contrast to our expectation. We suppose that it might be resulted in by operational and logistic inefficiency in sea transportation in China.

Previously, it only investigates that either exporter or importer as a membership of trade agreements impacts on the sea transportation of international trade cargo. However, the effect of both exporter and importer as members of the trade agreements on the sea transportation has not been considered. We hypothesize that both exporter and importer simultaneously as members of trade agreements have a significant effect on the sea transportation. Interaction terms that either exporter or importer is the membership of more than one trade organization, are deleted due to non-significance. Chow test displays that the coefficients of all dummy variables including interaction terms are jointly significant. Thus, the three interaction terms are newly added in the model (4-2), $WTO_{it}^{ex} \times WTO_{jt}^{im}$, $NAFTA_{it}^{ex} \times NAFTA_{jt}^{im}$, and $CAFTA_{it}^{ex} \times CAFTA_{jt}^{im}$, respectively.

$$\begin{aligned} Y_{ijt} = \alpha &+ \beta_1 WTO_{it}^{ex} + \beta_2 NAFTA_{it}^{ex} + \beta_3 CAFTA_{it}^{ex} + \beta_4 WTO_{jt}^{im} + \beta_5 NAFTA_{jt}^{im} + \beta_6 CAFTA_{jt}^{im} \\ &+ \beta_7 Brazil_{it}^{ex} + \beta_8 US_{it}^{ex} + \beta_9 Canada_{it}^{ex} + \beta_{10} Mexico_{it}^{ex} + \beta_{11} China_{jt}^{im} \\ &+ \beta_{12} Canada_{jt}^{im} + \beta_{13} Mexico_{jt}^{im} + \beta_{14} GDP_{ijt} + \beta_{15} SIM_{ijt} + \beta_{16} RFE_{ijt} \\ &+ \beta_{17} Distance_{ij} \\ &+ \beta_{18} WTO_{it}^{ex} \times WTO_{jt}^{im} + \beta_{19} NAFTA_{it}^{ex} \times NAFTA_{jt}^{im} + \beta_{20} CAFTA_{it}^{ex} \times CAFTA_{jt}^{im} \\ &+ \varepsilon_{ijt} \end{aligned} \tag{4-2}$$

As shown in Table 4-7, the interaction for WTO (CAFTA) positively impacts on the sea transportation when both exporter and importer is the membership of WTO (CAFTA), except for WTO in liquid bulk. The interaction for CAFTA is significant for four cargo sectors, but the interaction for WTO is significant for dry bulk, other cargo and all cargo sector. The interaction terms of both trade partners in the membership of the same trade agreement in Table 4-7, positively impact on sea transportation, providing the relevant support for our arguments in Table 4-6. Specifically, when both of trading partners are the memberships of NAFTA or CAFTA, it would be helpful to sea transportation between trade partners.

Table 4-7 The effect of both exporter and importer as the membership of trade agreements

	(1) Dry bulk	(2) Liquid bulk	(3) Other cargo	(4) Allcargo
GDP2016	1.847***	1.010***	3.097***	2.972***
	(37.36)	(16.62)	(93.54)	(92.19)
SIM2016	8.517***	7.610***	12.36***	11.90***
	(20.58)	(15.88)	(41.67)	(40.90)
RFE2016	-0.499***	-0.161*	-0.325***	-0.351***
	(-8.30)	(-2.18)	(-7.37)	(-8.12)
WTO^{ex}	-0.0520	0.593	-0.783	-0.365
	(-0.07)	(0.51)	(-1.61)	(-0.77)
$NAFTA^{ex}$	-9.240*	-3.026	-9.496***	-10.35***
	(-2.51)	(-0.62)	(-5.01)	(-5.51)

$CAFTA^{ex}$	-1.360**	1.273*	-0.859**	-1.017***
	(-3.17)	(2.20)	(-3.19)	(-3.83)
WTO^{im}	-1.793*	0.121	-3.069***	-2.590***
	(-2.22)	(0.10)	(-6.24)	(-5.41)
$NAFTA^{im}$	-6.049***	-3.073	-5.143***	-5.647***
	(-3.34)	(-1.77)	(-5.77)	(-6.40)
$CAFTA^{im}$	-0.776	-0.739	-0.694*	-0.713**
	(-1.88)	(-1.49)	(-2.50)	(-2.64)
$Brazil^{ex}$	1.571**	1.231*	1.472**	1.528***
	(3.22)	(2.34)	(3.24)	(3.40)
US^{ex}	.	.	4.999	5.365*
	.	.	(1.93)	(2.15)
$China^{im}$	-1.138***	-2.648***	-3.490***	-2.979***
	(-3.41)	(-6.69)	(-11.82)	(-10.22)
Distance	-0.000156 ***	-0.0000924***	-0.000224***	-0.000225***
	(-13.04)	(-6.50)	(-25.20)	(-25.83)
$WTO^{ex} \times WTO^{im}$	1.803*	-0.161	3.620***	3.183***
	(2.16)	(-0.13)	(7.05)	(6.37)
$CAFTA^{ex} \times CAFTA^{im}$	6.160***	4.449**	9.144***	8.752***
	(3.79)	(2.77)	(6.10)	(5.91)
cons	-25.83***	-8.810***	-58.16***	-54.32***
	(-16.99)	(-4.48)	(-59.54)	(-57.13)
sigma				
GDP2016	-0.0413			
	(-1.50)			
cons	6.264***	4.891***	5.010***	4.960***
	(8.37)	(92.18)	(151.09)	(152.60)
N	6672	4249	11414	11643

Note: t statistics in parentheses; * p<0.05, ** p<0.01, *** p<0.001.
US^{ex} in dry bulk and liquid bulk sector omitted because of collinearity; $Canada^{ex}$, $Mexico^{ex}$, $Canada^{im}$, $Mexico^{im}$, and $NAFTA^{ex} \times NAFTA^{im}$ (the interaction) omitted because of collinearity. Chow test displays that the coefficients of all dummy variables including interaction terms are jointly significant. The likelihood test shows that there exists the heteroscedasticity only in the dry bulk sector.

Furthermore, it is worthy to consider whether the effect of trade agreements on sea transportation depends on GDP of exporter or importer countries. We hypothesize that the effect of trade agreements on sea transportation depends on GDP of exporting or importing countries. Thus, the interaction terms of trade agreements and GDP of countries are added into the regression model in equation (4-3).

$$Y_{ijt} = \alpha + \beta_1 WTO_{it}^{ex} + \beta_2 NAFTA_{it}^{ex} + \beta_3 CAFTA_{it}^{ex} + \beta_4 WTO_{jt}^{im} + \beta_5 NAFTA_{jt}^{im} + \beta_6 CAFTA_{jt}^{im}$$
$$+ \beta_7 Brazil_{it}^{ex} + \beta_8 US_{it}^{ex} + \beta_9 Canada_{it}^{ex} + \beta_{10} Mexico_{it}^{ex} + \beta_{11} China_{jt}^{im}$$
$$+ \beta_{12} Canada_{jt}^{im} + \beta_{13} Mexico_{jt}^{im} + \beta_{14} GDP_{ijt} + \beta_{15} SIM_{ijt} + \beta_{16} RFE_{ijt}$$
$$+ \beta_{17} Distance_{ij}$$
$$+ \beta_{18} WTO_{it}^{ex} \times WTO_{jt}^{im} + \beta_{19} NAFTA_{it}^{ex} \times NAFTA_{jt}^{im}$$
$$+ \beta_{20} CAFTA_{it}^{ex} \times CAFTA_{jt}^{im}$$
$$+ \beta_{21} WTO_{it}^{ex} \times GDP2016_{it}^{ex} + \beta_{22} WTO_{jt}^{im} \times GDP2016_{jt}^{im}$$
$$+ \beta_{23} NAFTA_{it}^{ex} \times GDP2016_{it}^{ex} + \beta_{24} NAFTA_{jt}^{im} \times GDP2016_{jt}^{im}$$
$$+ \beta_{25} CAFTA_{it}^{ex} \times GDP2016_{it}^{ex} + \beta_{26} CAFTA_{jt}^{im} \times GDP2016_{jt}^{im} + \varepsilon_{ijt}$$

(4-3)

Table 4-8 The marginal effect of trade agreements depending on GDP of exporter or importer

	(1) Dry bulk	(2) Liquid bulk	(3) Other cargo	(4) All cargo
GDP2016	1.816***	1.068***	3.101***	2.976***
	(36.44)	(17.08)	(93.63)	(92.28)
SIM2016	8.719***	7.587***	12.02***	11.58***
	(20.81)	(15.73)	(39.96)	(39.24)
RFE2016	-0.499***	-0.162*	-0.319***	-0.345***
	(-8.31)	(-2.20)	(-7.23)	(-8.01)
WTO^{ex}	1.722	-1.110	-2.148***	-1.697**
	(1.96)	(-0.90)	(-3.85)	(-3.12)
$NAFTA^{ex}$	-8.972*	-3.133	-9.630***	-10.48***
	(-2.44)	(-0.64)	(-5.09)	(-5.59)
$CAFTA^{ex}$	4.143	14.11	-8.674**	-4.616
	(0.80)	(1.92)	(-2.61)	(-1.41)
WTO^{im}	-2.206*	1.165	-4.070***	-3.577***
	(-2.48)	(0.93)	(-7.25)	(-6.54)
$NAFTA^{im}$	-10.45	-42.71	96.70	76.91
	(-0.10)	(-0.43)	(1.84)	(1.48)
$CAFTA^{im}$	3.170	1.111	0.190	2.442
	(0.63)	(0.18)	(0.06)	(0.74)
$Brazil^{ex}$	1.029*	1.733**	1.915***	1.959***
	(2.06)	(3.21)	(4.15)	(4.28)
US^{ex}	.	.	4.730	5.113*
	.	.	(1.83)	(2.05)
$China^{im}$	-0.872*	-3.077***	-3.303***	-2.796***
	(-2.54)	(-7.53)	(-10.94)	(-9.39)
Distance	-0.000156***	-0.0000933***	-0.000226***	-0.000227***
	(-13.09)	(-6.57)	(-25.49)	(-26.10)

$WTO^{ex} \times WTO^{im}$	1.794*	-0.142	3.642***	3.204***
	(2.15)	(-0.12)	(7.10)	(6.42)
$CAFTA^{ex} \times CAFTA^{im}$	6.015***	4.169**	9.209***	8.792***
	(3.71)	(2.58)	(6.16)	(5.94)
$WTO^{ex} \times GDP\,2016^{ex}$	-0.433***	0.404***	0.336***	0.328***
	(-4.72)	(3.75)	(5.00)	(4.98)
$WTO^{im} \times GDP\,2016^{im}$	0.113	-0.271*	0.244***	0.241***
	(1.23)	(-2.54)	(3.64)	(3.66)
$NAFTA^{im} \times GDP\,2016^{im}$	0.935	8.455	-21.78	-17.66
	(0.04)	(0.40)	(-1.94)	(-1.59)
$CAFTA^{ex} \times GDP\,2016^{ex}$	-1.206	-2.873	1.741*	0.789
	(-1.04)	(-1.78)	(2.33)	(1.07)
$CAFTA^{im} \times GDP\,2016^{im}$	-0.902	-0.378	-0.219	-0.733
	(-0.80)	(-0.28)	(-0.28)	(-0.98)
cons	-25.08***	-10.28***	-58.17***	-54.33***
	(-16.45)	(-5.14)	(-59.57)	(-57.16)
sigma				
GDP2016	-0.0434			
	(-1.58)			
cons	6.311***	4.877***	5.000***	4.951***
	(8.45)	(92.18)	(151.09)	(152.60)
N	6672	4249	11414	11643

Note: t statistics in parentheses; * p<0.05, ** p<0.01, *** p<0.001.
US^{ex} in dry bulk and liquid bulk sector omitted because of collinearity; $Canada^{ex}$, $Mexico^{ex}$, $Canada^{im}$, $Mexico^{im}$, $NAFTA^{ex} \times NAFTA^{im}$, and $NAFTA^{ex} \times GDP\ 2016^{ex}$ omitted because of collinearity. Chow test displays that the coefficients of all dummy variables including interaction terms are jointly significant. The likelihood test shows that there exists the heteroscedasticity only in the dry bulk sector.

From Table 4-8, the interaction terms of WTO and GDP of exporter (importer) are significant for four cargo sectors. For the other cargo and all cargo, both the marginal effect of WTO on sea transportation expands when GDP of an exporting or importing country climbs. It means that the effect of the membership of WTO on transportation significantly depends on GDP of exporter and importer countries. However, the influence of WTO^{ex} (WTO^{im}) on the sea transportation of dry bulk (liquid bulk) sector contracts when GDP of the exporting (importing) country grows. For the sector of other cargo transportation, the marginal effect of the membership of CAFTA is significantly positive with the increase in GDP of the importing country. Those findings show that GDP of a country would make a complicated influence on the marginal outcomes of memberships of free trade agreements.

4.5 Implications and conclusions

This chapter investigates the effects of trade agreements and major exporting and importing countries on seaborne freight transportation services in terms of new measurement 'ton-miles', through using a regression model in dry bulk, liquid bulk, and other cargo sector. Unlike existing literatures, the output of sea transportation examined is in ton-miles, the product of tonnage of cargo transport and distance travelled. The measurement explains the costs of the sea transportation service enough more than those of only considering weights or distances.

For free trade agreements, WTO has a significant influence on exports of seaborne freight transportation services but does not encourage imports of seaborne container transportation. It reflects that the nature of WTO is encouraging the trade of semi-finished and finished products, especially importing to developed countries. A country with NAFTA or CAFTA membership contributes the less output of seaborne transportation. To the best of our knowledge, NAFTA and CAFTA are recognized as regional trade agreements, having limited members. Namely, the influences of the two trade agreements are restricted to member countries only. When only one of trading partners is the membership of NAFTA or CAFTA, it would be not helpful to sea transportation between trade partners. The argument is further supported by the following finding that the interaction terms of both trading partners in the membership of WTO or CAFTA positively impact on the sea transportation. In addition, the effect of the membership of WTO on sea transportation significantly depends on GDP of exporter and importer countries. Specifically, in other cargo and all cargo sector, when GDP grows, the marginal effect of joining WTO on sea transportation expands.

Another set of dummy variables are included to determine the country effect. The estimates have also identified the links of major exporting and importing countries to seaborne freight transportation. As indicated by $Brazil^{ex}$ and US^{ex}, Brazil and US contribute the output of seaborne container transportation as major exporters; however, for the variable $China^{im}$, the relationship between China as an importer and the output of sea transportation is negative, which is against our expectation. We suppose that it might be caused by operational and logistic inefficiency in sea transportation in China.

An important implication of this study is that the output of seaborne freight transportation is utilized to track and predict changes from the globe's and individual country's perspective. One way to assess sea transportation is to use the gravity model approach demonstrated in this study. Market participants in international sea transportation need to be better prepared to navigate their way through the challenges brought by the rebalancing global economic power.

Chapter 5

Conclusions and Future Work

5.1 Conclusions

This thesis studies into ocean transportation from three closely related topics: bunker fuel market, shipping bond market and the sea transportation of international trade cargo. It contributes to the existing shipping literature as follows.

The first study explores dynamic volatility spillovers across bunker fuel markets and freight markets in shipping industry. The empirical findings are concluded as follows. First of all, it is found that there exists an absolute volatility transmitter to other markets in each region and across regions, by examining static and dynamic volatility spillovers among bunker markets in Asian, European, American region and across regions. In detail, Singapore, Rotterdam and Houston are the net transmitters of spillovers to other markets in Asian, European and American region, respectively. Moreover, Singapore is also a leading market in the three markets, Singapore, Rotterdam and Houston. Thus, all bunker traders, shipping carriers and participants in global bunker markets need to pay more attention on the situation in Singapore market. Also, the volatility spillover effects are of great importance for stakeholders and investors in bunker markets to make risk management. When there is a possible shock to bunker price in the Singapore market, such as strikes, terrorism (military conflict), or bad weather, bunker prices of other bunker markets would be affected. The time-varying cross-market interdependences increase aggregate risk exposures. Those risk exposures could be incorporated into bunker derivatives pricing model to improve hedging performance. Secondly, shocks to Singapore bunker market significantly contributes to the forecast error variance of shipping freight markets, and the magnitude varies over the sub-segments of shipping freight markets. The volatility transmission from Singapore bunker market to shipping clean tanker market is higher than that to others. Thirdly, it provides the evidence of unidirectional interdependence between bunker spot and futures market in Singapore, which is affected by important economic events, such as the global financial crisis. Our findings are crucial for market participants and stakeholders to hedge operational and financial risk, by quantifying the volatility spillover effects within bunker markets, between Singapore bunker market and freight markets, and between Singapore bunker spot and futures market.

In the second one, we examine how shipping bond market makes an effect on shipbuilding market. Our study firstly constructs an indicator for shipping bond market, shipping credit spread. And then it identifies that an increased shipping credit spread directly has a negative effect on shipbuilding activities. Thirdly, global financial crisis makes a certain important effect on shipping bond market. Fourthly, shipping bond market imposes the more important effect on the shipbuilding market than shipping loans market. Moreover, the two-year lagged shipping credit spread could affect newbuilding contracts not only in current year but also the following year; the cumulative impact of shipping credit spread attained the highest degree in the following second year. Additionally, a contraction in shipping credit conditions could make a more remarkable effect on shipbuilding market than a credit supply expansion. The findings are beneficial to uncover the credit market condition and then to make expectations and decision for shipowners, shipping companies and market players in the shipping industry.

The third study investigates the effects of trade agreements and exporting and importing countries on seaborne freight transportation services by using a regression model on dry bulk, liquid bulk, other cargo and all cargo. In spite of previous literature, this study analyzes the sea transportation of international trade cargo from the new measurement of ton-miles. The empirical results include that the membership of the trade agreement, WTO (NAFTA or CAFTA), is positively (negatively) related to seaborne transportation. Also, it identifies the remarkable effect of major exporting and importing countries on seaborne transportation of international trade cargo, such as US and China. Those findings could be utilized to track and assess sea transportation, and then market participants in international sea transportation could be better prepared for navigating their ways through global challenges.

5.2 Future work

Although this thesis has addressed some issues from the perspectives of bunker fuel market, shipping bond market, and the sea transportation of international trade cargo, it is still worth noting that there exist research limitations. First of all, the first study only explores the volatility spillovers among 13 bunker ports due to lack of the data of all global bunker ports. Hence, it is deserved to make a further research, and there would be more interesting and complicated findings when having access to collect extra data on bunker ports over the world. Besides, the second study just provides the preliminary mechanism on how shipping credit spread plays a role in shipbuilding market. It could concern how different roles financial institutions and investors as sources of credit financing—for instance, commercial banks, mutual funds, and investment brokers—play in that process.

There are some other issues calling for future study. For bunker fuel market, global economic shocks and oil shocks could be incorporated into for further work. To extend the second study, it is worthy to explore how shipping credit spreads and shipping bond market could impact on other shipping markets and maritime economy as a whole. Moreover, for the sea transportation of international trade cargo, the research on green corridors that connect two or more major port hubs where zero-emissions shipping routes are proposed, is a popular trend in recent years. Future studies could also examine the ship emissions and the impact of COP26 Green Shipping Corridors and zero-emission shipping on the sea transportation of international trade cargo.

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