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A study of causal dynamics in the maritime shipping markets

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이 논문을 경제학석사학위 논문으로 제출함

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Abstract

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The maritime shipping industry has played a crucial role of carrying global trade demand among the international transport modes in accordance with the development of global economy. As maritime shipping markets as well as seaborne shipping industry are nearly perfect competitive markets, shipping companies easily enter and exit their businesses. Recently, the market conditions of the seaborne shipping industry have fluctuated due to both short-term random effects and the structure. Both short-term random effects and structure work as parts of the internal mechanism in the shipping freight system which causes dynamic behavior. The theoretical background in the mechanism is based on the supply and demand model. The supply and demand model in the freight system explains

that owners of ships adjust supply of fleet to changes in demand for trade. Also, charterers adjust freight rates to changes in the volume of trade, however, they often fail to make immediate adjustments in freight rates due to existing demand. Ultimately, this causes an imbalance in which fleet of ships will be oversupplied and then freight rates rapidly fall. This clearly explains that flows of information about changes in demand and supply in the seaborne shipping freight markets affect the dynamic behavior within the industry. In this context, this study not only focuses on analyzing causality of demand, supply, and freight rates within a single shipping market, but also extends to investigate causal dynamics between the three major seaborne shipping markets: tanker, dry bulk and container.

This study extensively analyzes literature on determinants of a freight rate, causality between seaborne shipping indices and macroeconomic variables, and the methodology of Granger causality test. Firstly, determinants of a shipping price are the key factors which signal the market conditions. Secondly, it has been found by researchers that macroeconomic variables such as Gross Domestic Product, stock market returns, industrial production, and so forth and seaborne shipping indices are highly correlated and are in causal relationships. Thirdly, the Granger causality test can be conducted to detect causality between time series considering stationarity of data. This study conducts Granger causality tests using monthly time series data for the three shipping markets mentioned in the previous paragraph and estimates vector error correction models. Additionally, this study examines the presence of any long-run and short-run equilibrium relationships between the time series. Especially, this study uses China- and India-related time series as the countries have created high demand for commodity trade in the last decade.

There are two dimensions in the scope of this research: the dynamic behavior with a single market and the causal dynamics between multiple markets. Firstly, in terms of the dynamic behavior within a single shipping market, this study finds that there are strong Granger causality running from demand to price and from supply to price under the long-run equilibriums in the tanker market through the investigation of Granger causality. Also, this study detects the same causal dynamics in the dry bulk market. However, this study only finds a strong Granger causality running from supply to price in the container market. These empirical results indicate that demand, supply, and freight rates interact under the supply and demand model. With regard to the second scope, this study proves the causal dynamics between the three major maritime shipping markets. This research finds strong Granger causality running from demand for container trade to supply of bulk fleet and from demand for bulk commodity trade to container freight rates. As well, this study detects a strong Granger causality running from supply of bulk fleet to tanker freight rates. Lastly, this study discovers a strong Granger causality running from demand for crude oil to supply of container fleet and from supply of container fleet to tanker freight rates. These empirical evidences support that the maritime shipping markets are not perfectly separated but integrated. Furthermore, causality of demand, supply, and freight rates with the long-run equilibriums are derived from cointegrating vectors between time series. The cointegration of two time series indicates the long-run relationship and the integration of them.

This study revisits the determinants of a freight rate discussed in literature and concludes that shifts in supply and demand cause freight rate dynamics. This research also asserts that seaborne shipping markets are interrelated in the long-run or short-run, and shows that we should pay more focus on the time and the origins of fluctuations in the markets.

Keywords: Shipping markets, cointegration, vector error correction model, Granger causality

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Chapter 1. Introduction

1.1 Research background and research objective

In 2016, world seaborne trade exceeded 10.3 billion tons and ships carried 90% of global trade volume (UNCTAD, 2017). However, the financial crisis in 2008 which was originated from the subprime mortgage meltdown in the United States expanded its negative influence throughout the global shipping freight industry resulting in a recession. The seaborne shipping industry which is nearly a perfect competitive market allowing easy entry and exit of new business, enjoyed a spectacular boom during the mid-2000s attributable to the outperformance of the global economy (Kalgora and Christian, 2016). To be specific, the cycle of 2003-2008 boom was caused by an increase in demand for the volume of trade, the rapid growth of Chinese and Indian economies and the competitive orders for new ships.

However, the maritime shipping industry has undergone an unprecedented recession which has exacerbated the market conditions since 2008. The optimism about the market during the market upturn caused an excess supply of fleet and the economic stagnation in the rising countries even worsened the conditions. In practice, the Baltic Dry Index (BDI) by the London-based Baltic Shipping Exchange which is a market barometer for the dry shipping freights and a leading indicator of the global economy, has highly fluctuated since the end of 2008. BDI reached the highest nearly up to 12,000 in the mid-2008, and after the financial crisis, the index sharply declined below 1,000. The downward tendency has not been restored until lately to the level of during the upturn that BDI has stagnated in the range of 200~1,000.

In this context, it can be inferred that not only short-term random effects, so-called *noises*, but also the structure, which can be defined as internal workings or mechanisms of the shipping freight system, affect the dynamic behavior of the maritime industry (Taylor, 1976). As previously stated, the supply and demand model, which pervades the shipping freights structure, causes random fluctuations in freight rates. This clearly illustrates that the dynamic behavior of the shipping freight markets is affected by flows of information about changes in demand and supply in the industry. Numerous studies have pointed out the interrelated mechanism among determinants of shipping freight rates in a single shipping market. Koopmans (1939) firstly asserted that long-term shifts in operation costs and intermittent sharp growth of demand affect the movement of tanker freight rates. Similarly, Hawdon (1978) discussed that the determination of spot freight rate can be defined as the series of interactions between the supply of and the demand for tanker transportation. In the short-term, both the supply and demand are price inelastic. On the contrary, in the long-run, expected values of tanker freight rates will influence the supply for tanker services. Beenstock (1985) argued that in a competitive and homogenous freight market, the global seaborne trade volumes and freight rates affect the demand for shipping services proportionally and indirectly, respectively.

Although the shipping industry has evolved into different sectors depending on types of cargo parcels and types of fleet, the sectors have been driven by the same economic mechanisms: the business cycle and the supply and demand model (Stopford, 2009). In commodity markets, the interaction in the model of supply and demand affects volatility in prices (Pindyck, 2002). In the maritime industry, demand often precedes supply as shipping fleets are adjusted in response to fluctuations in trades. Freight rates increase as excessive demand exists, but shipping companies cannot expand fleets immediately due to existing demand (Scarsi, 2007). Ultimately, fleet capacity will be oversupplied, and freight rates will decrease. This may lead to a collapse in the industry. These mechanisms clearly illustrate that the shipping cycle balances the supply and demand in the maritime industry. In other words, the shipping cycle in the industry is a combination of the inelastic supply and fluctuations in the shipping demand which leads to volatility in freight rates (Kalouptsidi, 2014).

Based on the supply and demand theory which drives interaction among demand, supply, and freight rates in a seaborne shipping market, it can be expected that information of a single shipping market flows to another shipping market. The characteristics of each shipping market supports this assumption. Firstly, the dry bulk market generally handles raw materials whilst container ships transport semi-finished and finished goods. Raw materials are key to respond to demand for production. Secondly, the tanker market and the bulk market operate multipurpose vessels which are convertible into either one depending on type of demand for trade. For instance, a shipowner converts a multipurpose ship to a bulk ship when demand for bulk trade increases. If demand for crude oil increase, the shipowner will convert the multipurpose ship into a tanker carrier. Thirdly, the container market may respond to changes in the tanker market as oil consumption tends to increase during an economic boom to operate bulk ships to transport raw materials. Thus, it can be assumed that there causal dynamics exist among the major shipping markets.

Despite many empirical studies on the factors influencing on freight rates within a single sector in the seaborne shipping services, research on causal dynamics among the major seaborne shipping markets considering demand, supply, and freight rates is insufficient. Since the shipping industry is the integrated markets, it is important to extend the research scope to analyze causal dynamics between multiple markets. Hence, investigating causal relations among multiple shipping markets in the maritime industry will not only provide a better understanding of the characteristics of the freight system, but also will help prepare countermeasures for volatility in the market conditions. Thus, the aim of this study is at investigating causality among the dry bulk, tanker and container shipping markets using monthly time series data of demand, supply, and prices (freight rates) in each market through vector error correction (VEC) model estimations in the Granger causality analysis. This study also focuses on testing cointegration between variables as a cointegrating relationship indicates the long-run equilibrium relationship between variables.

Chapter 2. Literature review and research framework

2.1 Literature review

The literature on the volatility of freight markets have focused on analyzing the determinants of a freight rate. Previous studies have reached a consensus that a determination principle of freight rate exists within a single maritime shipping sector under the economic model of supply and demand. Besides, since a seaborne shipping index has been a leading economic indicator of the world economic growth and industrial production, this study also explores literature on testing causality between various shipping indices and demand, supply and other exogenous variables. [Table 2] describes that explanatory variables, independent variables and subjects of study vary depending on researchers.

However, none of literature has discovered any lead-lag relationship among the seaborne shipping sectors. This study not only accepts the consensus in preceding studies, but also extends the scope of study to investigation of causal dynamics among the representative shipping sectors including dry bulk, tanker and container considering demand, supply, and freight rates. Hence, this study categorizes existing literature on the maritime industry into two groups: determinants of freight rates, causality between shipping indices and macroeconomic variables. In addition, this study also explores literature which conducted Granger causality tests using energy- or commodity-related variables.

2.1.1 Determinants of a freight rate

Koopmans (1939) theoretically demonstrated that the demand curve for oil shipping and the short-run supply curve of tanker transportation are inelastic. The short-run supply curve of tanker service is inelastic when existing ships are fully occupied at times of boom. On the other hand, the short-term supply curve becomes elastic during a recession due to laid up fleets. He also argued that long-term fluctuations in tanker operation costs and sudden increases in demand for tanker services affect the changes in freight rates. Thus, it is important to focus on the long-run supply (tanker construction) as it reflects to changes in freight rates.

Zannetos (1966) developed the Zannetos model to test the relationship between spot freight rates and the volume of lay-ups in the tanker market using data of annual averages of tanker freight rates and mid-year forecasts of lay-ups for the period of 1961-1973. The Zannetos model assumed that spot freight rates shift while the lay-ups are fixed. He included the reciprocal inverse of tonnage of total tonnage laid up to protect that freight rates do not fall below specific level. The empirical results showed that despite substantial shifts in the supply curve during the period, volatility in tanker freight rates in the 1960s were not significantly correlated with the shifts in the volume of lay-ups.

Hawdon (1978) emphasized that both demand for and supply of tanker transportation are price inelastic. Any changes in demand and supply schedules are possibly to cause considerable fluctuations in freight charges. If tanker freight rates fall below rates available in the dry bulk trades minus other operating costs, the fluctuations can be modified through altering tanker ships into dry bulk ships. This mechanism of adjusting supply has played a significant role in the shipping industry, leading to the development of combined carriers.

Charemza and Gronicki (1981) showed that the general tendency of economic processes in the shipping and newbuilding markets is a complex dynamic structure characterized by lagged feedbacks including several exogenous variables. Using annual data from the period of 1961-1977, the study investigated the relationships among the volume of world foreign trade, transport capacity of the world fleet, freight rates and inflationary factors. As Shimojo (1979), Charemza and Gronicki ignored that supply and demand in the shipping industry are simultaneously adjusted. The study concluded that negatively correlated cost factors and expected freight rates determine nominal short-run freight rates, and positively correlated cost factors and a business cycle indicator affect long-term freight rates.

Beenstock (1985) focused on modelling the joint determination of freight rates and the demand for shipping. Beenstock (1985) described the freight market as a single competitive homogenous market. The study defined that ton miles per unit time period can be calculated under the theory that the demand for shipping services shift directly with the seaborne trade volumes and inversely with shipping freight rates. This research assumed that capacity of a ton of ship is constant, but freight rates and fuel prices affect ship speeds. The empirical results indicated that given competitive market hypotheses, balancing between demand by freight rate adjustments and the supply of shipping services in each period determines the equilibrium condition under the possibilities of non-market clearing.

Beenstock and Vergottis (1989) hypothesized that the rational expectation of shipping freight rates affects shipbuilding and scrapping activities using annual data over the period of 1950-1985. Beenstock and Vergottis referred to the theory used in Beenstock (1985) and assumed that shipowners maximize profits under perfectly competitive conditions. The empirical results proved that demand inversely reflects changes in freight rates as an incentive to use other types of transportation will be created by higher freight rates. Besides, Beenstock and Vergottis additionally pointed out that the supply of vessels varies inversely with the second-hand price of ships.

Evans (1994) discussed the efficiency of the bulk shipping freight markets in both the short-run and long-term perspectives. In the short-run, freight market is operated under the conventional economic model of perfect competition. The classical economic model explains that marginal cost should equal to marginal revenue to maximize shipowners' profits. However, since bulk shipping sector is global, differences in fuel efficiency cause the cost structures of ships to be different. On the contrary, in the long-run, economic growth in OECD countries and increase in population drive growth of demand for bulk cargoes including coal, iron ore, and crude oil and newbuilding activities increase supply of vessels. When the demand for dry bulk match the supply of vessels, the industry can use the best available technologies to produce at the lowest cost. However, in practice, it is impossible as demand often increases faster than supply. The study also pointed out that increase in demand for bulk trades which is almost perfectly inelastic and short supply of vessels can rise freight rates to the highest levels.

Kavussanos (1996) asserted that the freight market in bulk shipping sector fairly describes world tramp markets under the theory of perfect competition. Using monthly data from 1973:1 to 1992:12 of the aggregate spot freight index, the index of industrial production, the stock of dry-bulk fleet and semi-annual data of the freight rate indices for Handysize and Panamax vessels, the aggregate time charter rates, the index of bunker prices and the freight rate index for Capesize vessels, the study investigated that market-clearing spot freight rates in the bulk shipping sector directly reflect industrial production, demand for shipping services and the price of bulk fleet. However, the study detected an inverse relationship between spot freight rates and the size of fleet as oversupplied capacity negatively affects freight rates. This research has a thread of connection with Koopmans (1939), Zannetos (1966) and Hawdon (1978).

Adland and Cullinane (2006) highlighted that as one of the most important economic variables, the role of the spot freight rate is critical in order to have a better understanding of the price mechanism in the shipping industry. As the recent literature mostly have only used parametric approaches to analyze system dynamics in financial economics, this study investigated the dynamics of the freight rates in the tanker shipping sector through estimating a nonparametric diffusion model. The study contended that a slow adjustment of supply (shipbuilding and demolition) to unexpected changes in demand means the long production time for newbuilding. The empirical findings showed that a nonlinear stochastic model can describe that the dynamics of the tanker spot freight rates. The volatility of the tanker spot rates increased in response to the fluctuation in the level of freight rates.

Radonja and Jugović (2011) pointed out that the shipping industry is separated into several markets from the whole but is a complex system between the supply and demand of shipping capacity for cargo parcels, passenger, shipbuildings, demolition, and second-hand ships, referring Glavan (1992). This study also asserted that due to the cyclical nature of the shipping market, interrelation exists among different shipping markets including the freight market, the sales and purchases market, the shipbuilding market and the demolition market. Radonja and Jugović (2011) found that the volume of cargo being traded influences the freight rates and the earnings are the driving sources for investors and shipowners to be motivated with investing activities.

Jugović et al. (2015) found that there are five factors affecting the demand for shipping services including world economy, global seaborne trade, average achieved profits, geopolitical events and transport costs. On the other hand, world fleet, fleet productivity, newbuilding, shipbreaking and freights are the five factors influencing the supply side in the shipping industry. The study pointed out that mutual functioning exists among the factors, and the mechanism ultimately determines the freight model in the industry. The study also stated that buyers and sellers find an acceptable price at the point where the supply and demand curves intersect. In practice, buyers and sellers consider the amount of time to adjust supply. The short-run equilibrium allows more time for shipowners to adjust supply (commissioning and decommissioning activities) responding to the shifts in freight rates.

[Table 1] Research on the freight rate mechanism considering demand and supply

Author(s)	Conclusion
Koopmans (1939)	· The short-run elasticity of demand was found to be 0.3, which is enormously low. Since the supply of capacity is limited, the supply curve is expected to be extremely elastic at a freight rate corresponding more or less to production costs, and extremely inelastic in its higher ranges.
Zannetos (1966)	· During 1961-1973, the changes in mid-year forecasts of volume of lay-ups were not statistically correlated with the changes in annual averages of tanker freight rates.
Hawdon (1978)	· The long-run profitability of tanker shipping industry is influenced by the tanker investment decisions which private tanker owners modify to tie to forecasted volumes of oil exports.
Shimojo (1979)	· The price elasticity of tankers in relation to the size of vessels is in the range of -0.5 to -0.7. · Size effects differed depending on the time, which recorded -0.011 and -0.793 for 1973:08 and 1975:12, respectively.
Charemza and Gronicki (1981)	· The inversely correlated cost factors and freight rates can determine nominal short-run freight rate predictions. · The asymmetric Walras modification law can determine real short-run freight rates. · Positively correlated cost factors, and a business cycle indicator which was derived by Suzuki's theory (Shimojo, 1979), can determine freight rates in long-run.

[Table 1] Research on the freight rate mechanism considering demand and supply (Cont'd)

Author(s)	Conclusion
Beenstock (1985)	· The level of freight rates is inversely associated with the elasticity of supply of shipping services. · Under the possibilities of non-market clearing, the supply and demand for shipping services in each period can be balanced through an adjustment of freight rate.
Beenstock and Vergottis (1989)	· Freight rates, voyage costs and running costs in relation to lay-up costs determine lay-up. · In the long-run, shipbuilding and scrapping determine the fleet size. · The multiplication of the size of fleet trading in the dry bulk sector and the average speed is proportional to supply.
Evans (1994)	· An increase in demand for volume of bulk trades is extremely inelastic. · Freight rates will reach the highest in the short supply of vessels.
Kavussanos (1996)	· Volatility was particularly high in the industry corresponding to random external shocks, such as 1973-74 oil shock just after stock market crash, 1980-81 oil crisis and the invasion of Kuwait in 1990. · Since an over-supply negatively impacts on freight rates, the spot freight rates are in the inverse relationship with the size of vessel.

[Table 1] Research on the freight rate mechanism considering demand and supply (Cont'd)

Author(s)	Conclusion
Adland and Cullinane (2006)	· A slow modification of supply (newbuilding and demolition) to random shifts in demand explains the long time for production of newbuilding. · The dynamics of the tanker spot freight rates can be estimated through a nonparametric diffusion model.
Radonja and Jugović (2011)	· The seaborne shipping industry is interrelated under its cyclical property, by freight markets, sales and purchases markets, and newbuilding and scrapping markets. · Freight rates are influenced by demand (trading volumes) and investors and shipowners are driven by earnings.
Jugović et al. (2015)	· World economy, global seaborne trade, average achieved profits, geopolitical events, and transports are the factors which affect the demand for shipping transportation. · World fleet, fleet productivity, shipbuilding, shipbreaking, and freights influence on the dimension of supply in the shipping industry. · Commissioning and decommissioning activities (supply) can be adjusted corresponding to shifts in freight rates.

2.1.2 Causality between seaborne shipping indices and macroeconomic variables

Kim (2008) investigated the dynamic causal relationships among the BDI, fleet capacity, and Chinese GDP and analyzed the effect of changes in Chinese economy influencing on BDI and fleet capacity. This study argued that the BDI has significantly fluctuated since 2001 due to constant growth of Chinese economy. Chinese economy has changed the global shipping flows as the trade volume of China was rated number two in the world in 2006 and totaled US$9,693 billion, which is more than four times greater than US$2,492 billion in 2000. In addition, Chinese demands for coal and iron has constantly increased due to the preparations for hosting the 2008 Summer Olympic Games in Beijing, the Expo 2010 Shanghai and other global events. The study detected unilateral causality running from Chinese GDP to the BDI and fleet capacity, respectively. The study also found that random shocks in Chinese GDP increase the BDI and fleet capacity while random shocks in fleet capacity declines the BDI. Besides, the effect of a random shock in Chinese GDP to the BDI found to be larger than the influence of a shock in fleet capacity on the BDI with a longer duration.

Bakshi et al. (2011) claimed that the fluctuations in the BDI have the ability of forecasting variations in global stock returns and other returns in of commodity indices. The study emphasized that the BDI is a proxy of the state of the economy as the calculation of BDI reflects observations from the investment activities. Although several researchers oppose to the evidence that the BDI is the indication of the economic circumstances, Bakshi et al. (2011) highly relied on the perspective that a drop in the shipping prices signals a dip downturn. This research found several empirical findings that the coefficients in forecasting regressions of stock returns on the growth rate of the BDI were highly positive and the growth rate of the BDI and commodity returns were positively related. Additionally, increase in the BDI leads to the growth of industrial production. These findings were common in most of the cases of sample countries used in the analysis.

Chung and Kim (2011) studied the impact of fluctuations in oil price on dry bulk freight rates and investigated interdependency among dry bulk freight rates. This research applied the estimations of a vector autoregressive (VAR) and a vector error-correction (VEC) models in the short-run and the long-run equilibriums to test whether changes in international crude oil prices influence on the dry bulk freight rates such as the BDI, Baltic Capesize Index (BCI) and Baltic Panamax Index (BPI). In addition, the authors explored whether interrelated relationships exist among the BDI, BCI and BPI to consider the shipping industry's volatile and dynamic characteristics. The empirical approximations indicated that the fluctuations in the international crude oil price positively affect the BCI at lag one and the BPI responds to a fluctuation in the BCI after three months. Furthermore, the effect of shocks in the BPI on the BCI was insignificantly small. Thus, the study concluded that the effect of changes in crude oil price on the shipping freight indices differ from index to index.

Kim (2011) defined that the world economy went into a depression due to the subprime mortgage crisis in 2008, which triggered the global financial crisis and financial market turmoil. The study analyzed whether the BDI, BCI, BPI, USD to JPY (Japanese Yen) exchange rate and Dow Jones Stock Index are co-integrated and the variables are under any equilibrium relationships. Since the retrieved data were time series, the author applied two types of impulse response function, GIRF (Generalized Impulse Response Function) and AIRF (Accumulation Impulse Response Function) to explore the interdependent dynamics. Besides, an impulse response function allows investigating the response in a freight index to a fluctuation in the financial variables such as USD to JPY exchange rate, Dow Jones Stock Index and other data of volatility. After performing Johansen cointegration and Engle-Granger (E-G) causality tests, the null hypothesis of inexistence of cointegrating vector was rejected at the 5% significance level. The empirical results in this study illustrated that the increases in USD to JPY exchange rate negatively impact on the freight indices. In addition, volatility in the Down Jones and in Chinese imports damagingly affect the freight indices. Lastly, this research concluded that that multivariate time series analysis is the foremost methodology to understand the dynamics of the shipping industry.

Alizadeh (2013) asserted that since seaborne shipping is one of the most volatile markets, agents in the shipping industry are exposed to financial risks due to predominated fluctuations in freight rates. To manage the risk, market participants have used long-term contracts including time- or period-charter and affreightment. However, since long-term contracts have downsides such as long-term physical commitment, poor trading activities under the contract and other deficiencies, thus the forward freight agreement (FAA) was offered as an alternative. The FAA allows two counterparties to adjust a freight rate for a certain type of cargo or type of vessel. According to Alizadeh (2013), the FAA has played a significant role in the global shipping industry in terms of risk management. This study found that shifts in the FAA prices during 2007-2011 positively affected trading volume and this fact is analyzed due to a momentum effect that more transactions are encouraged by higher returns. Additionally, this research obtained that trade volume and volatility in the FAA prices tend to contemporaneously move.

Apergis and Payne (2013) argued that the ability of tracking and anticipating economic activity has been a constant attempt of academic researchers. Although the use of a single proxy or multiple leading indicators of the world economy have been disputed, the explanatory power of predictive information of economic variables such as oil prices, returns on financial assets, shipping indices and industrial production have been broadly proved in many empirical studies. A commodity price such as oil price has been a persistent topic in terms of the effect of random shocks in cyclical variations (Hamilton, 2003; Killian, 2008). However, the authors pointed out that the number of research on the shipping industry has lacked despite the industry's highly volatile supply structure. Global demand for raw materials either positively or negatively impact on the structure of the maritime shipping industry in terms of shipping price. This study specified that the BDI reflects the global shipping price for commodities including coal, iron ore, grain and other raw materials. This study used daily panel data of stock market returns, interest rates on short-term and long-term bonds, commodity prices of the G-7 countries over 27 consecutive years from 1985 and monthly panel data of industrial production and the BDI from 1985 to 2012. The study revealed that the BDI yielded a linkage with financial asset markets.

Lin and Sim (2013) empirically approached to the research objective of whether growth in trade improves the income levels of the Least Developed Countries (LDCs) reported by the United Nations. Since Robertson (1940) defined international trade as an “engine of growth” which not only improves living standards of a country, but also drives economic development, trade and income levels are encouraging factors for low income countries to have economical competitive power. This study assumed that there is a positive causal relationship between trade and income and questioned whether the causality boosts living standards and ultimately results in economic development of an underdeveloped country. The research chose the BDI as the dependent variable since primary goods occupy most of the exports in the LDCs. The study estimated that a 1% increase in trade lifts real GDP per capita by in the range of 0.48% and 0.53% on average and reemphasized the importance of trade for developing countries.

Bildirici et al. (2015) argued that the BDI has played an important role as one of the leading indicators on the cost of seaborne shipping and the foremost proxy of the world seaborne trade volume and manufacturing activity. This study also emphasized that the BDI and world economy tend to co-move in reflecting to economic and financial fluctuations due to either a boom or a recession. During an economic upturn, demand for raw materials increase to satisfy growth in production and investments. Consequently, trade volumes of dry bulk, crudes and other raw materials increase accordingly. On the other hand, during an economic depression, production capacity is not fully utilized, and it ultimately causes decrease in demand for raw materials. Using the yearly data from 1965 to 2010, the study detected a cointegrated relationship between the BDI and the US GDP with the empirical evidence that the crisis regime of the US economy tends to last for 3.13 years. Thus, the research concluded that the BDI is the foremost barometer to predict a decline in GDP for the US.

Kim et al. (2016) investigated the relationship between freight indices and a stock price index of a shipping firm by estimating VEC and VAR models using weekly data of the BDI, CCFI (China Containerized Freight Index), HRCI (Howe Robinson Containership Index) and the stock price of H Company in South Korea during 2012 to 2015. This study highlighted that high volatility is one of the most central characteristics of the shipping industry, thus the durations of an expansion and a contraction of the market are irregular. Especially, shipping companies in South Korea have suffered since the subprime mortgage crisis of the US in 2008 due to dwindled seaborne trade volume. This study focused on analyzing the impact of a real economy index of the maritime industry on the stock price of a domestic shipping company. The research chose the stock price of an enterprise as a dependent variable since stock return describes a firm's overall value including capital, cash flows, tangible assets and so forth. The authors found that all of the shipping indices including the BDI, CCFI and HRCI were negatively correlated to the stock price index in the short-run.

Zhang and Tong (2017) discussed that Chinese economic position has been crucial to predict the global economy and the China's significant seaborne trading volume has attracted many investors' attention since shipping prices are proxies of economic booms or economic downturns. This research contracted annual data of Chinese GDP and the BDI during 2000 to 2015 from the National Bureau of Statistics of the People's Republic of China and the Wind Financial Terminal and the Value 500 Investment Navigation. The authors asserted that the BDI and economic growth are interdependent, and the BDI tends to precede economic growth, thus the shifts in global seaborne trading explain the changes of GDP. Wu and Chen (2010), Li and Zhao (2011), Lin and Sim (2013), Bildirici et al. (2015) and Zhang and Tong (2017) have a common understanding of that the frequency of international trade influences on the shifts of world economy and the BDI reflects the global trade volume. Zhang and Tong (2017) detected a positive unidirectional causal relationship running from the BDI to China's GDP, but not vice versa.

Killian and Zhou (2018) contended that a seaborne freight index such as the BDI captures variations in real economic activities. Although there has been no consensus that cyclical fluctuations in global real economic activities can be determined by observing shifts in the seaborne shipping indices, a broader research have chosen proxies such as the BDI, BCI, BPI, and BHI (Baltic Handysize Index) to analyze contemporaneous movement of the shipping freight rates and GDP. The authors asserted that during an economic slowdown, price of commodities decrease as demands for commodities including raw materials, semi-finished and finished products decline since unanticipated fluctuations in international real economic activities are associated with such mechanism. While several researchers have focused on measuring volatility in the prices of industrial commodities including copper, iron or iron ore, other studies have focused on analyzing fluctuations in world GDP or in the world seaborne trade volume of raw materials. This study discussed that not all models are applicable to forecast commodity prices while estimating models with the BDI is the most reliable. This research found that the global commodity price increased in 2016 after the partial recovery of the developed economies except China.

[Table 2] Studies on causality between seaborne shipping indices and macroeconomic variables

Author(s)	Dependent variable(s)	Independent variable(s)	Results
Kim (2008)	BDI	· Fleet capacity · Chinese GDP	1) Chinese GDP → BDI 2) Chinese GDP → Fleet capacity 3) Shocks in Chinese economy positively influence on the BDI while shocks in fleet capacity negatively affect the BDI.
Bakshi et al. (2011)	BDI	· Stock market returns · Commodity returns · Rate of industrial production	1) An increase in the BDI positively pursues higher stock market returns. 2) A higher growth rate of the BDI positively influences on commodity returns. 3) An increase growth rate of the BDI subsequently increases the growth rate of industrial production.
Chung and Kim (2011)	· BDI · BCI · BPI	International crude oil prices	1) The shocks in the international crude oil prices positively affect the BCI at lag one. 2) The BPI responds to a shock in the BCI after three months. 3) The effect of changes in the BPI on the BCI was relatively small.

[Table 2] Studies on causality between seaborne shipping indices and macroeconomic variables (Cont'd)

Author(s)	Dependent variable(s)	Independent variable(s)	Results
Kim (2011)	· BDI · BCI · BPI	· USD/JPY exchange rate · Dow Jones Stock Index	1) Increase in USD/JPY exchange rate inversely impact on the BDI, BCI and BPI. 2) In addition, volatility in the Down Jones and in Chinese imports negatively impact on the BDI, BCI and BPI.
Alizadeh (2013)	FFA prices	Seaborne trade volume	1) Fluctuations in the FAA prices increased international seaborne trading volume. 2) Shifts in the FAA prices and changes in seaborne trading volume tend to co-move.
Apergis and Payne (2013)	BDI	Stock market returns	1) The BDI plays an appropriate role as an indicator of the fluctuations in financial asset markets. 2) Shifts in the shipping price of raw materials co-move with the shifts in the BDI.
Lin and Sim (2013)	BDI	GDP	1) 1% expansion in trade increases GDP per capita by around 0.5% for the LDCs.

[Table 2] Studies on causality between seaborne shipping indices and macroeconomic variables (Cont'd)

Author(s)	Dependent variable(s)	Independent variable(s)	Results
Bildirici et al. (2015)	BDI	GDP	1) The BDI and GDP are cointegrated. 2) Improvements of the BDI positively affect the growth in US GDP.
Kim et al. (2016)	· BDI · CCFI · HRCI	Stock price index	1) BDI → Stock price index (Short-run) 2) CCFI → Stock price index (Short-run) 3) HRCI → Stock price index (Short-run)
Zhang and Tong (2017)	BDI	Chinese GDP	1) BDI → Chinese GDP (Short-run) 2) Chinese GDP ↛ BDI (Short-run)
Killian and Zhou (2018)	BDI	Real economic activities	1) The BDI is the strongest proxy to analyze fluctuations in real economic activities. 2) The BDI increased in 2016 after the partial recovery of the developed economies excluding China.

2.1.3 Granger causality analysis

Sims (1972) has been renowned for its pioneering characteristic in the use of causality analyses. The author argued that the “Quantity Theory”, which is a body of macroeconomic framework, illustrates that money stock and the present dollar measures of economic activity are in a causal relationship, however, empirical findings of a degree of positive association between the variables have lacked in quantity. Under the assumption that variations in income may equally co-move with variations in money stock, this study modeled money and U.S. GNP (Gross National Product), and performed Sims tests based on the Granger (1969) criterion to derive a causal relationship between aggregate quarterly data of money and U.S. GNP, which resulted in the existence of a unilateral causality running from money to GNP. The description of statistical results of this study explained that GNP is exogenous with money stock, and reconfirmed the common agreement that changes in income are associated with changes in money.

On the contrary, Kraft and Kraft (1978) claimed that the policy option of energy conservation is not acceptable since economic activity may be adversely influenced by the policy. According to Kraft and Kraft (1978), the policy of energy preservation implies the assumption that a unidirectional causality running from energy to economic activity is in the presence. This study performed Granger causality tests to detect any causal relationships between energy consumption and GNP. Interestingly, the authors failed to detect a causality from energy to GNP while a unilateral causality running from GNP to energy for the postwar era was in the presence.

Akarca and Long (1979) analyzed the causal relationship between total energy consumption and total employment using monthly data from 1973:1 to 1978:3. The authors conducted empirical testing of causality developed by Granger (1969) and focused on isolating the two time series to separate random shocks or 'innovations' from the systematic dynamic property of the series. The empirical findings indicated that there was a unilateral causality running from total energy consumption to total employment. The estimations also suggested that there was an inverse impact from a fluctuation in energy consumption on the employment variable with a delay of eight months. The response of the employment to a change in the energy consumption was completed by the end of the twelfth month so that using monthly data was appropriate rather than annual data.

Yu and Hwang (1984) highlighted the importance of energy consumption on economic activity since the global economy experienced a significant recession caused by the Middle East oil embargo in 1973. This study reexamined the causality between energy consumption and GNP to prove the contradiction between Kraft and Kraft (1978) and Akarca and Long (1980). Akarca and Long (1980) opposed to Kraft and Kraft (1978) that the empirical results based on the unilateral causality running only from GNP to energy consumption during 1947-1974 are spurious. Thus, Yu and Hwang (1984) adjusted the study period to 1947-1979. The results of performing both of Sims and Granger causality tests indicated that despite high correlation between energy inputs and GNP, no causal relationship between the variables were not in the existence.

Glasure and Lee (1997) discussed the causal dimensions between energy consumption and GDP for both Korea and Singapore applying the methods of cointegration and error correction modeling. This study utilized annual time series from 1961 to 1990 of energy consumption and GDP for the countries and used Akaike's Information Criterion (AIC) to find the optimal lag length for the causal mechanism. The research firstly performed stationary tests including a constant and a trend in these estimations. The null hypothesis of non-stationarity could not be rejected, however, first-differenced data, $I(1)$ data, were rejected at the 5% significance level. In the second place, cointegration tests were conducted with undifferenced data, and E-G two-equation error-correction models were estimated with $I(1)$ data. The study empirically proved that bilateral causal relationships between energy consumption and real GDP for both cases of Korea and Singapore were in the existence.

Kwon and Shin (1999) explored whether present economic activities in South Korea have predictive power to forecast stock market returns through cointegration tests and Granger causality tests based on estimations of VEC models. The general relationship between real economic activities and stock market returns in the U.S. has been enormously investigated by numerous studies. In general, the studies used time series data of prices of financial asset and fundamental economic activities such as productivity growth, growth rate of GNP, inflation and so forth. Despite plentiful studies analyzing the causal relationship among stock market indices and economic activities for the U.S., research on the economic role of the stock market returns in Asian countries including Korea, Taiwan, Hong Kong, Singapore, and so forth has lacked. The cointegration and the estimation of

VEC model in this study illustrated that stock price indices and the productivity, foreign exchange rate, trade balance, and money supply for such Asian countries were cointegrated, which explains that a long-run equilibrium exists. Nevertheless, in some cases, economic activities preceded the fluctuations in stock prices.

Asafu-Adjaye (2000) estimated Granger causality models to examine the causal relationship between energy consumption and economic growth of in four Southeast Asian countries including India, Indonesia, the Philippines and Thailand. The author argued that despite numerous studies on the causal relation between energy consumption and macroeconomic variables, the empirical findings have not reached a consensus. This study drew a conclusion that the primary factors of conflicting empirical results are the variety of methods and testing procedures applied in the studies. The earlier analyses tended to employ the approach of estimating ordinary least squares (OLS) without considering the dynamic nature of time series data. However, since Granger and Newbold (1974) proved that most macroeconomic time series variables are non-stationary, recent studies have started regarding the dynamic property of time series data to avoid misleading relationships between economic variables. The empirical findings of this paper illustrated that energy, income and prices of the Philippines and Thailand were in a mutual causal relationship while energy consumption unilaterally Granger causes income in both India and Indonesia.

Shiu and Lam (2004) pointed out that China has experienced a rapid economic growth and arisen as the second largest electricity consumer in the world. The role of electricity in China has functioned as a driving force accelerating economic growth and its demand has constantly increased after the 1970s. This literature applied VEC models to investigate the causal relationship between electricity consumption and GDP for China from 1971 to 2000. The Augmented Dickey-Fuller (ADF) unit root and Johansen maximum likelihood tests were performed prior to Granger causality tests. The authors found that electricity consumption and GDP for China were in the cointegration relationship and electricity consumption unidirectionally Granger caused GDP for China during the study period. This study also found that electricity consumption and GDP for China were positively correlated. However, the estimations failed to find a reverse Granger causality running from GDP for China to electricity consumption during the same research period.

Notteboom and Vernimmen (2009) argued that bunker fuel is a substantial expense since bunker fuel accounts for around 50% of costs of a single voyage operation (Lee, 2017). Recently, the bunker prices have considerably fluctuated with the impact on the design of shipping services on the Europe-Asia trade. This paper discussed that shipping companies consume huge amounts of bunkering oil each year to operate the international fleet of cargo, commercial and military vessels. HFO (Heavy Fuel Oil) accounts for about 80% of the total bunker fuel in the world and its types are categorized into several types by the quality and the process. Constant fluctuations in HFO subsequent to changes in the cost of HFO and market forces. Similarly, Cariou and Wolff (2006) analyzed causal relationships among the bunker adjustment factor, bunker price, the freight and charter services on the Europe-Asia container shipping. The study found that a rise of HARPEX (Harper Petersen Charter Rate Index) increases the freight rate of west bound by 1.6% and concluded that impact of charter freight rates differed from westbound and eastbound.

Kim (2010) established an energy-growth hypothesis to test the general relationship between the variables in terms of cointegration and causality. According to Kim (2010), Field and Grebenstein (1980), Berndt et al. (1981), Pindyck and Rotemberg (1983) and Jorgenson (1984) asserted that energy has played a role of input which precedes productivity growth. However, the recent linkage between energy consumption and economic growth has unprecedentedly decoupled in several industrialized countries such as the United States and the United Kingdom. This study applied unit root methods and cointegration tests to detect long-run equilibriums between GDP and TPE (Total Primary Energy) of various countries. Besides, the causality test proposed by Granger (1969) enables to analyze a causal relationship between the variables based on both VAR and VEC models. The author found that TPES Granger cause GDP of the United States in most of the period in between 1890 and 1967 while TPES does not Granger cause GDP of the U.S. during 1968-2003. However, it was found that there a unidirectional Granger causality running from TPES to GDP of the U.S. exists in 2004.

Zhang and Wei (2010) asserted that the key representatives of the commodity markets are the gold and the crude oil markets, thus it is crucial to obtain significance of such markets from the perspective of price forecast by analyzing their cointegration and causal relationships. The dynamics of the commodity markets and the variances in gold and crude oil prices can be interpreted and predicted, respectively, by the common price trend from the analysis. The empirical results distinguished consistent trends between gold and crude oil prices and found that significant positive correlation with a coefficient of 0.9295 existed during the study period of 2000:1 to 2008:3. Besides, the consistent trends were in a long-run equilibrium and the changes in in gold prices were Granger caused by the volatility in crude oil prices.

Maxwell and Zhu (2011) addressed that LNG is expected to account for 12.4% of the US natural gas consumption by 2030, which is comparably larger than current level of approximately 2.5%. Since LNG is a substitute of natural gas, a natural gas price is anticipated to be a key determinant of LNG imports. Recently, LNG has often traded under short-term contracts rather than long-term contracts with spot deliveries being shipped to international markets maximizing returns. In this regard, LNG netbacks are highly influenced by both natural gas prices and LNG shipment costs. This study investigated the causal relationship between U.S. LNG imports, the Henry Hub price of natural gas, and LNG transportation costs using monthly time series data during 1997-2007. This research performed Granger causality tests by estimating VAR models and analyzed impulse response functions. The empirical results explain that shocks in natural gas prices and in transportation costs Granger cause U.S. LNG imports. It also appears that the speed of response of U.S. LNG imports to shifts in natural gas prices was faster than in shipping costs.

Heo and Seo (2012) emphasized that it is crucial to determine the major factors which cause fluctuations international crude oil prices since changes in the prices significantly impact on both energy-exporting and energy-importing countries. The authors focused on investigating how fully-developed international crude oil markets response to variations of production and inventory through estimations of VEC models using monthly data of prices of five major spot prices of international crude markets, OPEC crude oil production, and

U.S. crude oil inventory from 1983:7 to 2000:5. This study put emphasis on the level of the crude oil inventory, particularly the U.S. crude oil inventory, as fluctuations in the monthly non-strategic inventory of the U.S. crude oil were found to have an empirical relationship between West Texas Intermediate (WTI) spot and futures prices referring to the conclusion of Considine and Heo (2000). The empirical results revealed that changes in both OPEC crude oil production and the U.S. crude oil inventory statistically either rise or drop the OPEC crude oil production in the long-run.

Croux and Reusens (2013) highlighted that a drop in the domestic stock prices often causes economic recessions in a country. However, a decline in the domestic stock prices occasionally failed to provide true signals for the future economic activity. For example, an economic boom rather than an economic recession led to the stock depression in 1987. Hence, the issue of whether fluctuations in the stock prices have predictive power to forecast the future economic condition. The authors investigated the predictive power for the future domestic economic activity using quarterly data of domestic stock prices of the G-7 countries in the period of 1991:Q1-2010:Q2. Based on VAR and VEC models, this study analyzed which the slowly changing components or the rapidly changing components have better projecting power. The empirical results showed that the slowly shifting domestic stock prices have larger forecasting power than the quickly changing domestic stock prices to predict the future economic activity. This evidence was found in both cases of a multi-country setting and a single-country setting.

[Table 3] Studies performing Granger causality tests

Author(s)	Dependent variable(s)	Independent variable(s)	Results
Sims (1972)	Money stock	U.S. GNP	1) A change in money stock Granger causes a change in U.S. GNP. 2) GNP is exogenous with money stock.
Kraft and Kraft (1978)	Energy consumption	GNP	1) GNP unilaterally Granger causes energy consumption for the postwar period. 2) Energy consumption does not Granger cause GNP.
Akarca and Long (1979)	Energy consumption	Employment	1) Energy consumption Granger causes employment. 2) Energy consumption inversely impacts on employment. 3) It takes 12 months for employment to completely reflect changes in total energy consumption.
Yu and Hwang (1984)	Energy consumption	GNP	1) Energy consumption and GNP are positively correlated. 2) Energy consumption and GNP are not in any causal relationships.

[Table 3] Studies performing Granger causality tests (Cont'd)

Author(s)	**Dependent variable(s)**	**Independent variable(s)**	**Results**
Glasure and Lee (1997)	Energy consumption	GDP	1) Korea: Energy consumption↔GDP 2) Singapore: Energy consumption↔GDP
Kwon and Shin (1999)	Stock price returns of Asian countries	· Productivity · Foreign exchange rate · Trade balance · Capital supply	1) Stock price returns and the four independent variables are cointegrated. 2) In general, stock price returns Granger cause the macroeconomic variables. 3) A stock price index is a leading indicator of a fundamental economic activity.
Asafu-Adjaye (2000)	Energy consumption	Income	1) India and Indonesia: Energy consumption → Income (Short-run) 2) The Philippines and Thailand: Energy consumption ↔ Income (Short-run)
Shiu and Lam (2004)	Electricity consumption	Chinese GDP	1) Electricity consumption Granger causes Chinese GDP. 2) Chinese GDP does not Granger cause electricity consumption. 3) Electricity consumption and GDP for China are positively related.

[Table 3] Studies performing Granger causality tests (Cont'd)

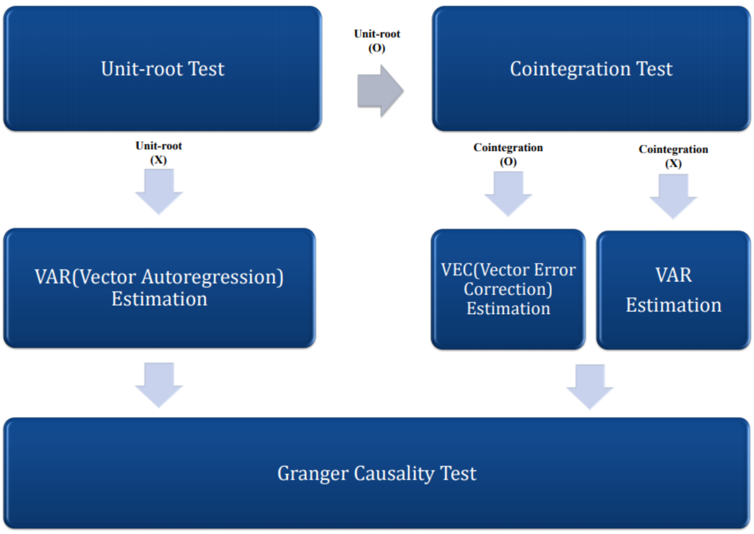
Author(s)	Dependent variable(s)	Independent variable(s)	Results
Cariou and Wolff (2006)	HARPEX	Europe-Asia freight rate	1) Increase in HARPEX Granger causes increase in the overall freight rates by 1.7%. 2) Increase in HARPEX Granger causes increase in the westbound freight rates.
Kim (2010)	Energy consumption	GDP	1) TPES Granger causes GDP of the United States in the majority of years between 1890 and 1967. 2) TPES does not Granger cause GDP of the United States in the period of 1968-2003. 3) TPES Granger causes GDP of the United States in 2004.
Zhang and Wei (2010)	Gold prices	Crude oil prices	1) Gold prices and crude oil prices are positively correlated. 2) Volatility in crude oil prices Granger causes changes in gold prices, but not vice versa.

[Table 3] Studies performing Granger causality tests (Cont'd)

Author(s)	Dependent variable(s)	Independent variable(s)	Results
Maxwell and Zhu (2011)	· Natural gas prices · LNG shipping costs	U.S. LNG imports	1) Shocks in natural gas prices Granger cause the US LNG imports. 2) Shocks in shipping costs Granger cause the US LNG imports. 3) The US LNG imports response shocks in natural gas prices faster than shocks in transportation costs.
Heo and Seo (2012)	· U.S. crude oil inventory · OPEC crude oil production	International crude oil spot prices	1) Changes in the U.S. crude oil inventory Granger cause international crude oil spot prices. 2) Changes in the OPEC crude oil production Granger cause international crude oil spot prices.
Croux and Reusens (2013)	Stock price index	GDP	1) Stock price index Granger causes the GDP growth at 5% significance level. 2) The Granger causality of the slowly changing stock price index is significant.

The literature select the Granger causality test for their research methodology, Granger causality can be defined under two assumptions: the past value causes the present value or future value and a causal linkage contains unique information about an impact (Lin, 2008). The pros of Granger causality are that it captures causality which correlation does not imply and it provides information about which factor causes effect on another factor. The literature conducting the Granger causality test mostly uses time series to find any unique unilateral or bilateral property of time arrow (Lin, 2008). Granger (1969) proposed that if an independent variable Granger causes an explanatory variable, then the past of the independent variable has information which helps predict the future value of the explanatory variable better. The steps of the Granger causality test are illustrated as follows:

<Fig. 1> Testing for Granger causality



2.2 Research framework

2.2.1 Research methodology

(1) Cointegration test

A cointegration test is simply for testing whether the error in the cointegrating equation is either stationary or non-stationary. There are two main cointegration methods that have widely been used by literature which are: 1) E-G estimation method and 2) the Johansen (1988, 1991) maximum likelihood method (Anderson, 1971). E-G test uses the residuals of the cointegration regression. Since these estimated residuals are not free-standing time series, another set of critical values are used in E-G cointegration tests (Anderson, 1971; Dhrymes, 1997). Also, the E-G method requires a large sample size to prevent having possible estimation errors and it can only test the cointegrating relationship between a maximum of two variables (Brooks, 2008). On the other hand, the Johansen test uses either maximum eigenvalue statistic or trace statistic and its estimation model is as follows:

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-1} + B x_t + \varepsilon_t \qquad (2.1)$$

In the Granger causality test to analyze time series, an important question is whether to difference the time series. The raw data $\{x_t\}$ is replaced by the first-order differenced series $\{x_t - x_{t-1}\}$ (Box and Jenkins, 1970). As most economic and financial time series tend to be non-stationary, but that differencing often produces stationary results. However, differencing throws any information included in the long-run equilibrium relationship between time series. To analyze time series without differencing, cointegration tests should be conducted to find any long-run equilibrium relationship between the time series.

When x and y are integrated of order one $(I(1))$, but the error term in the relationship between x and y, u is stationary, and then it can be said that x and y are cointegrated (Granger and Newbold, 1974; Stock and Watson, 2011). For instance, if there are two time series x and y, and they are integrated of order one $(I(1))$, the linear combination of these x and y, $z_t(= x_t - \beta y_t)$, also is $I(1)$ with unit roots. However, there can be β which makes z_t an $I(1)$. If x and y are cointegrated, the linear combination z_t becomes stationary and this leads to the long-run equilibrium relationship between x and y. When x and y are integrated of order one $(I(1))$, but the error term in the relationship between x and y, u is stationary, and then it can be analyzed that x and y are cointegrated (Granger and Newbold, 1974; Stock and Watson, 2011). According to Eq. (2.1), the Johansen test is based on a VAR model that y_i is expressed in two terms, the difference term Δy_i and the long-run equilibrium term $\mathit{\Pi} y_{t-1}$. In a VAR model, Π implies the long-run equilibrium relationship between $I(1)$ series and the rank of Π means the number of cointegrating vector.

The Johansen cointegration test is a multivariate generalization of the ADF test in which generalization can be defined as the investigation of linear combinations of time series for unit roots (Dwyer, 2015). The maximum likelihood, which is an estimation strategy of the Johansen test, enables to examine all cointegrating vectors when there are more than two time series. In general, if there are n non-stationary time series, there at most $n - 1$ cointegrating vectors exist. If cointegration analysis shows that a cointegrating vector is in the presence, it can be inferred that the time series will not drift away from the long-run and will return to equilibrium levels following any short-run drift that may occur (Anderson, 1971).

This study conducts Johansen cointegration tests as the methodology has some pros over the cointegration tests developed by Engle and Granger (1987). The E-G test includes any error occurred in the first stage transfers to the second stage. Also, the results highly depend on the selection of the dependent variable. However, the estimations of the Johansen test are not only obtained from one stage, but also based on the matrix rank and the eigenvalues thus the results are sensitive to the choice of the variable (Pereira, 2013). Through the Johansen estimation method, all cointegrating vectors of more than two variables can be estimated through maximum likelihood statistics. The null hypothesis of a trace test is there are at most r cointegrating relations against the alternative of m cointegrating relations. Order the n eigenvalues by size provides the information whether there cointegrating vectors exist (Dwyer, 2015). On the other hand, trace statistics do not depend on the subordinate relationship between time series. Furthermore, asymptotic critical values are given by Johansen and Juselius (1990). Thus, this study conducts Johansen cointegration tests and use trace statistics to investigate the long-run equilibrium relationships between the time series of demand, supply and freight rates in the seaborne shipping markets.

(2) Unit root test

Approaches to find the existence of a unit root in parametric time series models have recently appealed a good deal of interest in both economical and statistical theories (Dickey an Fuller, 1979; Phillips and Perron, 1988). Since economic time series imply trending behavior or non-stationarity in the mean, detecting the presence of a unit root has the great importance as a part of Granger causality test (Zivot and Wang, 2006). A unit root, which can be defined as a time series which mean and variance change over time, means non-stationarity. In general, statistical analysis is conducted under the assumption that a time series is stationary, however, many economic variables are non-stationary. If a time series which has a unit root is used in an empirical study, there is a high possibility of having spurious regression (Yule, 1926; Granger and Newbold, 1974). A spurious relationship is often found in time-series data, where spurious regression is a regression which provides misrepresentative statistical evidence of a linear relationship between non-stationary and independent time series (Granger and Newbold, 1974). Spurious regression often results in a high R^2 value even when two variables are independent of each other and causes serial correlation errors (Giles, 2007).

The most widely conducted methods for testing unit roots are the ADF and the Phillips-

Perron tests (Dickey and Fuller, 1979; Phillips and Perron, 1988). The firstly developed unit root test, DF (Dickey-Fuller) tests have an issue of an error term in a model being autocorrelated, thus ADF tests are constructed (Dickey and Fuller, 1981). Although ADF tests are widely used in economic and financial time series, they should be used with caution due to a high possibility of tests being biased towards Type II error (Schwert, 1989).

ADF tests include fitting the regression model:

$$Y_t = \alpha + \rho Y_{t-1} + \delta t + u_t \qquad (2.2)$$

Serial correlation will cause a problem thus lags of the first differences of Y_t should be included in the regression of ADF tests. The PP tests non-parametrically correct any serial correlation and heteroskedasticity in the errors u_t through modification of the ADF test statistics (Newey and West, 1987). Despite a low possibility of having a Type II error compared to ADF tests, a Type I error may occur if a coefficient of serial correlation between time series is high. In addition, the testing power of PP test can be low if samples are finite (Schwert, 1989). Since both ADF and PP tests have pros and cons, this study conducts both the ADF and the PP unit root test to test following hypotheses:

$H_0 = Y_t \sim I(1)$ (Non-stationary)

$H_1 = Y_t \sim I(0)$ (Stationary)

After conducting the ADF and PP tests, if t-statistics are statistically insignificant, the null hypothesis is accepted. This means that unit roots are in the presence and the time series is non-stationary. On the contrary, the null hypothesis is rejected if t-statistics are statistically significant than critical value. This means that unit roots are not in the presence thus the time series is stationary.

(3) Granger causality test with vector error correction (VEC) model estimation

The presence of cointegration relationship explains that there are long-run equilibrium relationships among the time series. Hence, Granger causality among the time series exists in at least unilateral direction (Shiu and Lam, 2004). Sargan (1964) firstly introduced the VEC estimation model and Engle and Granger (1987) highlighted that the model not only tests long-term and short-term causal relationships among cointegrated time series, but also correct disequilibrium.

For investigating the causal dynamics among the seaborne shipping markets, this study uses the definition of causality suggested by Granger (1969). Granger causality can be defined as a statistical concept of causality that is based on forecast (Sørensen, 2005). According to Granger (1969), if X_t Granger causes Y_t, then historical values of X_t have information which helps forecast Y_t better than the information contained in the historical values of Y_t alone. To test Granger causality, Eq. (2.3) and Eq. (2.4) can be defined in respect of stationary time series Y and X.

$$Y_t = a_1 + \sum_{i=1}^{p} \beta_{1,i} Y_{t-i} + \sum_{i=1}^{p} \gamma_{1,i} X_{t-i} + \varepsilon_{1,t} \quad (2.3)$$

$$X_t = a_2 + \sum_{i=1}^{p} \beta_{2,i} Y_{t-i} + \sum_{i=1}^{p} \gamma_{2,i} X_{t-i} + \varepsilon_{2,t} \quad (2.4)$$

[Table 4] Interpretation of the results for Granger causality tests

Case	$H_0: \beta_{1,i} = 0 \quad \forall_i$	$H_0: \beta_{2,i} = 0 \quad \forall_j$	**Causality**
Case I	Reject	Accept	$Y \leftarrow X$
Case II	Accept	Reject	Y ← X
Case III	Reject	Reject	Y ↔ X
Case IV	Accept	Accept	No causality

Source: Reorganized from Lee (2017)

In the case of Eq. (2.3), it can be determined that X Granger causes Y when the obtained sum of square errors (SSE) significantly increases with the past values of X. Similarly, in Eq. (2.4), Y Granger causes X when SSE significantly rises with the lagged values of Y. If time series Y and X are non-stationary and they are in the long-run equilibrium relationship, Eq. (2.3) and Eq. (2.4) can be transformed into VEC terms as Eq.

(2.5) and Eq. (2.6) (Choi et al., 2016).

$$\Delta Y_t = \alpha_3 + \sum_{i=1}^{p-1} \beta_{3,i} \Delta Y_{t-i} + \sum_{i=1}^{p-1} \gamma_{3,i} \Delta X_{t-i} + \delta_3 ECT_{t-1} + \varepsilon_{3,t} \qquad (2.5)$$

$$\Delta X_t = \alpha_4 + \sum_{i=1}^{p-1} \beta_{4,i} \Delta Y_{t-i} + \sum_{i=1}^{p-1} \gamma_{4,i} \Delta X_{t-i} + \delta_4 ECT_{t-1} + \varepsilon_{4,t} \qquad (2.6)$$

$$\text{where } ECT_t = Y_t - \alpha_0 - \beta_0 X_t \qquad (2.7)$$

ECT_t in Eq. (2.7) is an error correction term (ECT) which indicates the long-run equilibrium relationship between time series Y and X. In other words, the coefficients δ_3 and δ_4 of ECT_{t-1} indicates the speed of adjustment to the equilibrium when there is a drift from the long-run equilibrium at $t-1$. Eq. (2.5) and Eq. (2.6) enable testing the short-run equilibrium and the long-run equilibrium, respectively. Thus, estimating VEC models have been consistently conducted not only in the research on causality between seaborne shipping indices and economic indicators, but also in the studies on energy consumption and economic growth (Sims, 1972; Kraft and Kraft, 1978; Akarca and Long, 1979; Yu and Hwang, 1984; Glasure and Lee, 1997; Kwon and Shin, 1999; Asafu-Adjaye, 2000; Shiu and Lam, 2004; Kim, 2008; Notteboom and Vernimmen, 2009; Kim, 2010; Zhang and Wei, 2010; Bakshi et al., 2011; Chung and Kim, 2011; Kim, 2011; Maxwell and Zhu, 2011; Heo and Seo, 2012; Alizadeh, 2013; Apergis and Payne, 2013; Croux and Reusens, 2013; Lin and Sim, 2013; Bildirici et al., 2015; Choi et al., 2016; Kim et al., 2016; Zhang and Tong, 2017; Killian and Zhou, 2018). The short-run causality is defined as conducting Granger causality tests in terms of differenced ΔY and ΔX while the long-run causality can be tested with ECTs. In addition, it also can be tested whether the short-run and long-run causality exist simultaneously through 'strong causality' (Choi et al., 2016).

Thus, this study conducts Granger causality tests using monthly time series of supply, demand, and freight rates of the tanker, dry bulk, and container maritime markets to investigate the long-run and the short-run equilibrium relationships. However, when time series Y and X are not under the long-run equilibrium, this research tests Granger causality after differencing Y and X then only detects the short-run causality.

2.2.2 Research hypotheses

The hypotheses in this study consider that the maritime industry is characterized by the interdependent dynamics among the shipping markets. The maritime industry is integrated with the four shipping markets: the freight market, the sale and purchase market, the newbuilding market and the demolition market. They are closely related to each other with the linkage by cash flow (Stopford, 2009). Firstly, freight revenue from the freight market is the prime source of cash inflow for shipping companies which drives investment activities. Secondly, the demolition market provides cash inflow just as the freight market. Dealers purchase outdated ships to scrap from ship operators during downturns. In the demolition market, scrapping obsolete ships and losing ships decrease shipping capacity. In contrast, the sale and purchase market deals with second-hand ships. In the sale and purchase market, transactions over second-hand ships between shipowners occur through shipbrokers, but both cash inflow and cash outflow are simultaneously generated. The transactions do not affect fleet capacity. Lastly, the newbuilding market requires negotiations between buyers and sellers before signing shipbuilding contracts. Shipping companies order newbuilding to shipyards, resulting in cash outflow and expansion in fleet capacity.

(1) Hypothesis I: Short-run or long-run equilibrium relationship exists among demand, supply and freight rates within a shipping sector

The economics theory of supply and demand argues that in a competitive market, an economic equilibrium for price and quantity intersects at the point where quantity demanded equals with quantity supplied (Frank, 2014). Likely, the market structure of the shipping industry is close to perfect competition and the supply and demand functions dominate the shipping freight markets (Harlaftis et al., 2002). Based on these mechanisms, decision makers including shipping companies, charterers and financers in the shipping industry control the fleet capacity in the short-run and maximize profits by reducing operating costs in the long-run. On the demand side, during the economic booms, seaborne commodity trades grow, resulting in increase in freight rates.

In practice, constantly low-level of freight rates have been detected due to the persistent imbalance of demand and supply in the shipping industry over the last few years. Although the global trade volumes improved by 2.6% in 2016 compared to 2015, the supply of fleet capacity increased faster than trade volumes, resulting in overcapacity and decrease in freight rates and earnings (UNCTAD, 2017). Since the shipping industry has been characterized by interrelated dynamics, detecting the existence of short-run or long-run equilibrium relationship among determinants of the shipping market conditions is crucial to predict business cycles.

(2) Hypothesis II: Lead-lag relationship exists between the dry bulk and the container shipping sectors

Although the volatility in the freights of bulks, container and tanker shipping sectors are different in the short-run, fluctuations in the freights of one type of ship would influence the freights of other types of ships in the long-run as they are in the same market (Stopford, 2009; Hsiao et al., 2013). In addition, some shipowners convert a multipurpose vessel into another type of ship to manage greater commodity demand than supply of capacity. From 2006 to 2007, some multipurpose vessels, originally used for container shipping, were converted into bulk ships to earn more profits from greater demand for dry bulk than container commodities (Stopford, 2009).

It is also argued that increase in demand for dry bulk commodities may lead to increase in demand for container trades since dry bulk ships have mainly shipped raw materials while container ships have carried semi-finished or finished products (UNCTAD, 2012; UNCTAD, 2018). Hence, during an economic upswing, the bulk shipping sector may lead the container shipping sector in response to increase in demand for dry bulk commodities. However, changes in the container shipping sector may lag before fluctuations in the bulk shipping sector in reflecting the shifts of the economic climate due to an economic downturn.

(3) Hypothesis III: Bilateral short-run equilibrium exists between the dry bulk and the tanker shipping sectors

In the maritime industry, there is a high degree of flexibility among ship types and cargo types. Substitutable ships such as combined carriers, are designed to provide transport services of commodities for several markets (Stopford, 2009). Although each shipping sector in the seaborne shipping market is specialized with its unique types of cargo parcels and types of ships, a high degree of interchangeability among fleet types demonstrates interdependence of the industry (Tsolakis, 2005).

Especially, the dry bulk and the liquid bulk shipping sectors are interconnected with the combined carriers, operated in both dry bulk and tanker shipping sectors. When demand for crude oil and petroleum products increases during an economic boom, shipowners alter combined carriers into tanker ships from dry bulk ships to maximize capacity utilization and earnings. During an economic upturn, shipowners order more ships and newbuilding activities grow. However, ordered ships are delivered after a considerable time period. Hence, the conversion causes increase in supply of capacity in the short-run (Klovland, 2002; Kumar, 2016). Thus, it is expected that the dry bulk and the tanker shipping freight markets are in the short-run interactive relationship under the business cycle.

(4) Hypothesis IV: The tanker and the container shipping sectors are interrelated

The long-term relationship between seaborne trade and the world economy describes that over long periods, industrial growth of individual regions has driven seaborne commodity trades, leading to the development of the world economy. The rapid growth of the industrial economies of Europe and Japan in the 1960s was an important factor in the dramatic growth of demand for raw materials and energy commodities until the sudden stagnation in the 1970s (Stopford, 2009). The industrial economies created the high level of imports of containerized raw materials and energy, including iron ore, crude oil and petroleum products in producing refined and complex products and operating factories in the 1960s (Ross et al., 1987). Besides, in the 1960s, the tanker capacity grew to meet demand for liquid bulks trades and the size of tankers increased over 200,000 dead-weight tonnage (dwt). Thus, the demand and supply of the tanker and container shipping markets were influenced by the industrialization of the global economy.

On the other hand, industrial economies often mature over long periods. The economic structure of the developing countries which caused the increase in seaborne trade shifted over time, leading to a lower demand for raw materials and energy. In the 1970s and 1980s, Europe and Japan became less resource-intensive, and their demand switched from construction to stock-building of durables as the economies matured (Stopford, 2009). This led to the stagnation in the maritime industry in the 1970s. Recently, China has played an important role of growing demand for containerized basic materials and energy.

2.2.3 Research outline

This study begins with Chapter I introducing research background and research objective. The research background describes the recent trend in the maritime shipping industry and provides basic literature review on the supply and demand mechanism. The last section of Chapter I specifies the research motive and the purpose of the study.

Chapter II provides an extensive literature review on the shipping industry. This study categorizes the literature into three themes: determinants of a freight rate, causality between seaborne shipping indices and macroeconomic variables and Granger causality analysis. After the literature review on Granger causality analysis, this study emphasizes the pros of the methodology and provides the illustration of the steps in the Granger causality test. After reviewing literature, this study moves into the research framework. The research framework section includes research methodology, four research hypotheses which will be empirically tested and research outline.

Chapter III explains the characteristics of the maritime industry and its markets. This chapter introduces the seaborne shipping industry with an overview. This chapter not only gives a brief history of the industry, but also touch the organization of the industry and shipping economics. The last part of Chapter III highlights the major shipping markets: tanker, dry bulk and container markets.

Chapter IV describes the empirical analysis of this study. The first section explains the time series used in this research and provides descriptive statistics. The second section of

Chapter IV shows empirical results by hypothesis.

Chapter V concludes this research with two summaries of Granger causality tests within a single shipping market and between the major shipping markets, respectively. The last part of Chapter V discusses the contribution of this study and the limitations.

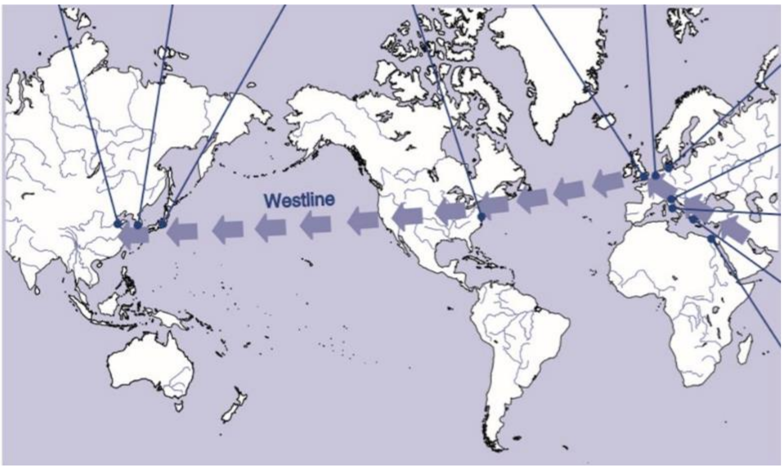
Chapter 3. The characteristics of the maritime shipping markets

3.1 The maritime industry

3.1.1 Introduction

The maritime shipping is an epic which has its root on the seaborne routes of the world Christopher Columbus pioneered, and the initial cargoes and parcels were transported by sea more than 5,000 years ago. This groundbreaking spirit consequently led to the development of supertankers, bulk ships, container ships, and the fleet of specialized vessels which carry a ton of cargo for every individual in the world (Radcliffe, 1985; Stopford, 2009). Economists agree that the role of ocean trade in economic development is significant in two aspects: productivity and accessibility. In his quote in *The Wealth of Nations*, Adam Smith put emphasis on the importance of the division of labour in capitalism with respect to globalization (Smith, 1937). The division of labour claims that the separation of tasks in a system not only increases productivity, but also improves accessibility for a business to a broader pool of market. In short, if each employee is concentrated into a unique task, more goods can be produced under the division of labour than what a cooperative system can produce. Furthermore, since local markets are insufficient to sell up the manufactured goods, transport plays a crucial role of revealing the power of division of labour that every kind of industry utilizes support from water carrier in transporting more cargoes to all over the world than what ground transport alone can be capable of.

<Fig. 2> The 'Westline'



Source: Stopford (2009), p.6

The leading commercial hub of seaborne trade has constantly changed with the movement from west to east. The arrows in the line of <Fig. 2> illustrate the movement heading east. The 'Westline' implies the history of seaborne development (Stopford, 1988). The first seaborne network was developed in the Arabian Gulf during 2000-3000BC through the trade of oil, copper and possibly ivory among the communities in the area. After the initiation, new seaborne routes were established between Northwest Europe-the Americas to transport raw materials from the Americas to European manufacturers. During 1833-1950, steel ships replaced wooden sailing ships as a part of the industrial revolution, and consequently sea trade experienced a rapid growth. As innovation continuously transformed shipping system, the complexity of shipping operation increased simultaneously. Subsequently, liner shipping services and tramping emerged and transported passengers and cargoes. Especially, tramp shipping services played an important role of carrying the gaps which the general liner services cannot cater for (Athanassiou, 2009). From 1950s onward, container and bulk transport system was developed on the basis of reducing labor costs with less expensive equipment and increase the size of shipping to exploit the cost advantages of economies of scale (OECD, 2003).

Seaborne trade unprecedentedly grew during 1950-2005 due to expansion of bulk commodity imports. Europe and Japan played a significant role of increasing maritime trade of raw materials for their heavy industries, however, after the two oil crises in the 1970s, trade growth was converged on the East Asia economies, such as South Korea and China, who were catching up Japan. Additionally, seaborne bulk shipping system developed as oil companies modified their strategy to deliver crude in larger volumes to refiners than the past and steel factories moved near coastal sites to supply iron ore readily. Consequently, the average capacity of tanker escalated from 12,500 dwt in 1903 to 564,763 dwt in 1977 (OTA, 1975; EPA, 2007). The average size of dry bulk carrier also increased from 24,000 dwt in the 1920s to 300,000 dwt in the 1980s on the similar pattern to tanker (Kristensen, 2012). Furthermore, shipping companies started containerizing general cargoes and parcels which would not fit in a standard 20 foot box of 20 feet long and this contributed to the development of global commerce (Stopford, 2009).

Hence, the history along the ‘Westline’ illustrates that the maritime industry has constantly changed to correspond with the development of the global economy. The history of ocean trade spread from Lebanon, where the first seaborne trade was initiated at, to Greece, Northwest Europe, the Americas, Japan, Korea, and China. The development of the maritime industry also progressed the innovation of the shipbuilding technology. Wooden ships were replaced by steel ships which have larger capacity, and containerization was initiated. The diffusion of the global trade was based on the need of raw materials to be transported to manufacturers in an industrialized country, and this trend followed the free flow of trade which the Bretton Woods Agreement clarified. Thus, it is not an exaggeration that the seaborne shipping has played a direct role in globalization.

3.1.2 Overview

The shipping industry has been such a global industry, which trade occurs through the dispersed commercial shipping hubs across the world. Hamburg, Shanghai, Hong Kong, Singapore, Busan, Tokyo, New York, Geneva are known to be the most competitive seaports (Verhetsel and Sel, 2009). Shipping is often defined as any trade between two geographical points or hubs, and the trend of shipping follows the notions of economies of scale in operation, network-based management, and the innovation of technology (Lun et al., 2010). Since seaborne shipping services require marine transport modes, ships, the main assets of the maritime industry, have played an important role of increasing mobility of cargoes and parcels. For a shipping company, ships are critical resources as vessels determine fleet capacity. Thus, vessel operations not only extensively influence on legal, tax, financial status of a shipping firm, but also induce the competition among shipping companies (Steele et al., 2001).

The global shipping industry and the world economic growth are inextricably linked and should be considered together. The maritime industry has continuously reflected the state of the world economy since the economic downturn of 2009. The prolonged effects of the subprime mortgage crisis have pressured on the seaborne industry with high uncertainty, such as weak demand for trade, unstable commodity prices, high crude prices. Furthermore, the recent development of digitalization, which has driven the rapid growth of electronic commerce (e-commerce), and the expansion of the liner shipping market also have influenced on change in the trend of the industry (Branch, 2007). Despite a below-historical average growth, in 2016, the maritime industry transport moderately improved in accordance with developments in the world economy that demand for transport services increased by 2.6% compared to 2015. Total volumes of international seaborne trade recorded 10.3 billion tons, which trade of cargo accounted for more than 260 million tons. Especially, tanker trade formed about 130 million tons of the trade volumes of cargo. This increasing trend can be interpreted as the impact of strong demand for international marine trade of emerging countries, especially China (UNCTAD, 2017).

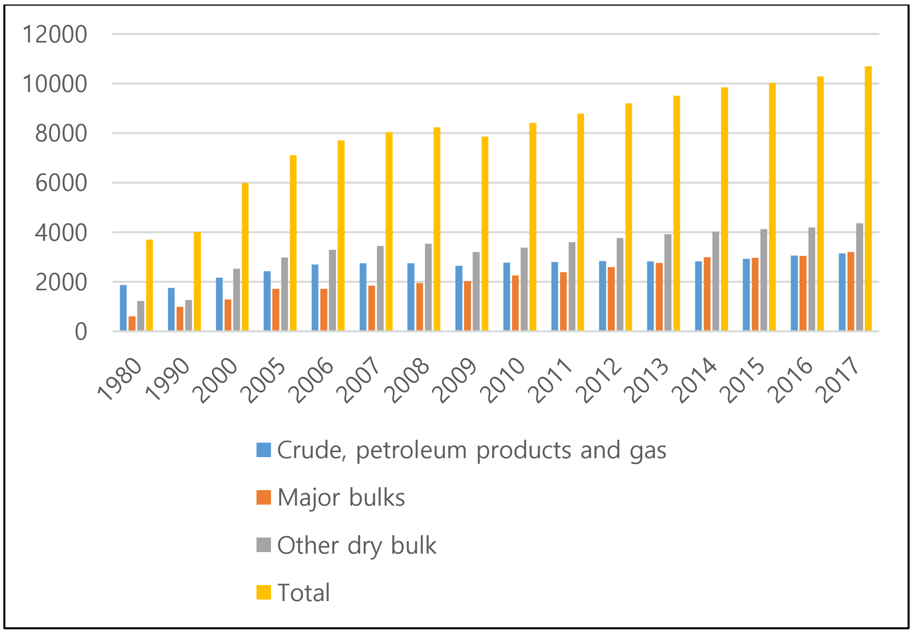
Above all, world merchandise shipping accounts for about 33% of the total maritime activity, including vessel operations, shipbuilding, marine resources, marine fisheries and other marine related activities, such as maritime tourism, marine information technology (IT) and so forth (Stopford, 2009). In 2016, the volumes of world merchandise trade only increased only 1.9% from 1.7% in 2015, due to a downturn in investment activity (WTO, 2017). On the contrary, the share of LDCs in merchandise exports almost doubled in 2017 compared to 10.3% in 2010. However, lower commodity prices have negatively impacted on heavy commodity-exporting countries, such as Africa, Latin America and the Caribbean, thus the rate is still below the 4.4% growth peaked in 2013 (UNCTAD, 2017). Likewise, world merchandise import has experienced a slowdown due to the recent economic recession in Brazil, demand for trade in developing countries recorded a mere increase of 1.1%. As the weakness in global demand for trade and the slowdown in economy are the cyclical factors, the significant fluctuation in the conventional linkage between trade and economic growth has started reflecting the structural shifts of globalization and supply-chain ownership (Bems et al., 2013; Hoekman, 2015).

[Table 5] Annual growth in volume of merchandise trade by region, 2015-2017 (%)

	Exports			**Imports**		
Regions	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**
Worldwide	2.5	1.8	4.7	2.5	1.8	4.7
Developed	2.3	1.1	3.5	4.3	2.0	3.1
North America	0.8	0.6	4.2	5.4	0.1	4.0
Europe	2.9	1.1	3.5	3.7	3.1	2.5
Asia	1.5	2.3	6.7	4.0	3.5	9.6
Latin America and the Caribbean	1.8	1.9	2.9	-6.4	-6.8	4.0
Developing & Transition	5.5	2.6	2.3	-5.6	0.2	0.9

Sources: Developed from UNCTAD (2017) and UNCTAD (2018)

<Fig.3> Growth in world maritime shipping trade, 1980-2017 (million tonnes)



Source: UNCTAD (2018)

3.1.3 The organization of the ocean transport system

In the past 50 years, the shipping industry has developed with a new shipping system based on modernization and technological innovation (Lim, 1998). The demand for different types of transport services has been continuously shifted due to economic pressures which the distribution of parcel size and differentiation of demand have created (Stopford, 2009). Although today's shipping market has separated into three distinct segments, bulk shipping, specialized shipping and liner shipping, the segments are closely related to each other through the sea transport system (Branch, 2014). Each segment handles different tasks and has different characteristics (Rodrigue, 2010; Levinson, 2016).

Bulk shipping is a distinctive business which transports large and bulky raw materials and semi-manufactured goods such as oil, iron ore, coal and grain through bulk fleet of shipowners (Stopford, 2002). Bulk ships typically complete about six trips with a single cargo every year, which explains that bulk vessels handle only few transactions. Six voyages are identical to six negotiations, so the annual revenue can be determined by six negotiations per voyage every year. In addition, indirect costs, such as costs of vessel operation, costs of cargo arrangement are low since services levels of bulk shipping are relatively lower than liner services and specialized shipping services. A bulk ship requires 0.5-1.5 employees per ship, thus a team of 25-75 employees can handle a fleet of 50 bulk vessels which worth $1 billion (Stopford, 2009). Hence, bulk shipping aims at minimizing the costs of transporting cargoes in large vessels.

Liner shipping is often described as 'general cargo shipping', it carries semi-manufactured and final products through container fleet of shipowners (Davies, 1986). Liner shipping often transports small cargoes and parcels that are relatively more valuable than bulk cargo parcels. The small bulk commodities include steel products, non-ferrous metal ores, malting barley and discarded paper (Stopford, 2008; Stopford, 2009). A container ship plays an important role in liner shipping that a single container vessel deals with 10,000-50,000 transactions per annum, thus a fleet of five container ships completes 50,000-250,000 revenue transactions each year (Stopford, 2013). As a container ship handles many transactions, each voyage carries so many containerized cargoes and parcels, liner shipping is an arrangement-intensive business. Since small and valuable cargoes are packed in a container, this business requires higher service levels than bulk shipping (Heins, 2013). Therefore, prices are set high, but often negotiated in the form of an agreement with major customers.

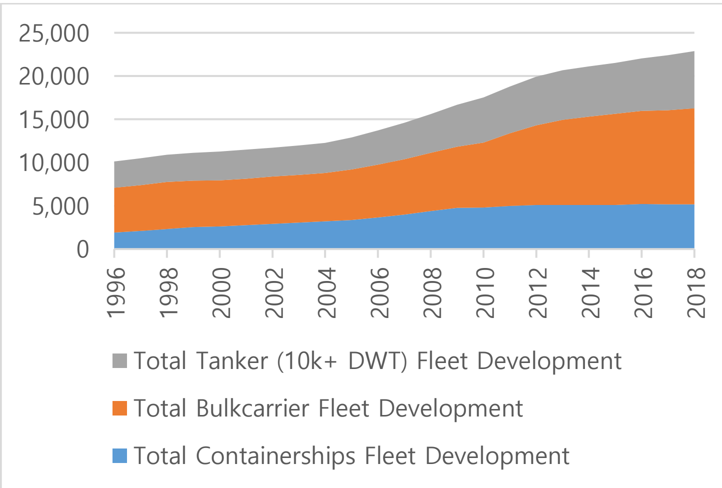
In the segment of specialized shipping, specialized fleet of shipowners carry heavy cargoes and sophisticated commodities such as motor vehicles, chemical and liquid cargoes (Clarksons Research, 2004). Specialized shipping is located between bulk shipping and liner shipping that an elaborate chemical tanker transports an average of 500 parcels per annum, however, the tanker may also carry individually negotiated spot cargoes (Stopford, 2009). Specialized shipping companies provide higher service levels of transport than operators of bulk transport and focus on investing in specialized vessels (Plomaritou and Papadopoulos, 2017). Some of the service providers in the specialized shipping segment tend to become a part of terminal to increase the level of integration in the cargo-loading processes and improve the condition of distribution chain (Jansson, 2012).

To sum up, although the three segments constitute the seaborne industry, the role of each segment is carrying out different tasks, and each segment has unique characteristics. Different tasks depend on the type and value of cargo and parcel and the volume of freight. Besides, amount of transactions which a type of ship handles, contractual conditions and supply-chain management are also influencing factors which determine what types of tasks each segment should execute and characteristics of each segment. The bulk shipping segment, as the most developed segment in the maritime shipping industry, had rapidly grown during the post-war period (Olesen, 2015). In the early stages of the segment, a fleet of bulk carriers had been responsible for transporting raw materials from notable industries, such as steel, aluminum, fertilizer, and so forth. However, the bulk ships are now mostly carrying coal, oil, iron ore, and grain in order to meet demand for merchant trade. On the contrary, the liner shipping segment is quite different from bulk shipping that freight rate in the segment is mostly based on a fixed rate under a service agreement. In the liner shipping, a fleet of container ships transport general cargo parcels including containerized cargoes, loose cargoes, boxes, parts of machinery, liquids and heavy cargoes (Frankel, 1989). Especially, liquid cargoes such as petroleum products and crude oil are carried by tanker ships. Lastly, specialized shipping services are generally provided for a special customer with a particular cargo type which is risky or fragile. Special shipping companies tend to heavily invest in ship design to improve operation performance to carry specialized freights.

3.1.4 The fleet

As an important asset of a shipping company, a ship determines what type of ship to order among various types and sizes of vessels. Additionally, choosing a ship depends on type of cargo, type of operation and commercial type. The number of world merchant fleet of vessels recorded 74,398, which cargo ships accounted for 63.8% (47,433 vessels) and 26.5% (19,722 vessels) for non-cargo ships (Clarksons Research, 2018). The world merchant fleet has continuously grown since the early 1990s, with a pint of acceleration in 2005 (UNCTAD, 2017b). The world fleet reached 1.9 billion dwt in 2017, which was almost doubled compared to 1.0 billion dwt in 2005. Bulk cargo fleet almost accounts for the half of the fleet, 29% and 13% for tanker fleet and fleet of container ships, respectively.

<Fig.4> The world fleet development by type of ship, 1996-2018 (No.)



Source: Clarksons Research

Bulk cargo fleet can be classified into two groups, tankers and bulk carriers. The tankers which often used in statistics are over 10,000 dwt, including Aframax, Handy, Panamax, Suezmax, VLCCs (Very Large Crude Carriers), tankers over 10k dwt and small tankers. These distinct types are for different trades, larger types are go into long-haul services while smaller tankers are for short-haul trades in general (Dimitriou, 2016). However, some trades are transported through either in a larger tanker or in a small tanker. The number of tankers decreased by 17% for January 2017 compared to 8,693 in January 2008 (Clarksons Research, 2018). Scrapping of tankers has caused demolition activities to be more active in recent years than the past. An increase in a shipbreaking activity is analyzed to be due to the recession in freight markets and low spot rates, and consequently, it led to the significant decline in the number of tankers (Karlis et al., 2016; Ahammad and Sujauddin, 2017).

The other classification of bulk cargo fleet is bulk carriers. A fleet of bulk carriers is composed of Capesize, Handy, Handymax, Panamax and combined carriers (Stopford, 2013). Particularly, combined carriers transport a combination of bulk, crude oil and ore (Clarksons Research, 2018; Stopford, 2009). Among these, Capesize, Handy, Handymax and Panamax are dry bulk carriers. A bulk carrier often transports the identical bulk cargoes. Cement carriers, chip carriers, open hatch and ore carriers are adhered to some bulk ships (Um and Roh, 2015). Bulk vessels under 50,000 dwt have cranes to place freights under the deck (Stopford, 2009). Raw materials such as, iron ore, coking coal, grain and so forth are the major dry bulk cargoes while agribulk, sugar, fertilizer, minerals, and steel products are minor bulk are the minor ones.

In the fleet of general cargo vessels, the most important type of ship is a container ship.

The number of container ship recorded 4,205 which accounts for 16.3% of the total general cargo fleet in 2007. Container ship fleet can be grouped into three parts: small (100-999 TEU: Twenty-foot Equivalent Unit), medium (1,000-2,999 TEU) and large (Over 3,000 TEU) container ships. Container ships were designed with box-shaped holds to securely stow containers in cells. Since the holds are placed under the deck, these holds not only require any locking devices, but also save time to unload containerized freights. In addition, the fleet of ro-ro ships in the world reached 3,848 vessels, and the size of a ro-ro ship is in between 100-50,000 TEU (Twenty-foot Equivalent Unit) (Stopford, 2009). Ro-ro ships transport wheeled cargoes such as automobiles, lifting trucks, semi-trailer trucks and so forth. Thus, loading and unloading time is shorter through a ro-ro ship than other container ships and this type of ship is favorable to short-haul voyages.

Specialized ships include reefer ships, chemical tankers, specialized tankers, automobile carriers, liquefied petroleum gas (LPG) and liquefied natural gas (LNG) tankers (Plomaritou and Papadopoulos, 2017). In 2007, the total fleet of specialized vessels was found to be 6,978. Reefer ships tend to carry refrigerated and palletized cargoes while chemical tankers transport chemical parcels. Automobile carrier general has multiple decks to stack up vehicles and gas tankers, such as LPG and LNG ships have freezing systems which contain the de-icing functioning. As the name hints, the design of a specialized vessel was modified to carry cargoes and parcels with dispatch. For instance, specialized ships for transporting small liquid parcels contain coated tanks.

3.1.5 The cost of freight transport

The revolution of the international trade has been positively affected by the numerous contributions of seaborne shipping, particularly with the effort of reducing the freight cost. In the early 2000s, the value of world import recorded \$9.2 trillion with the freight cost of \$270 billion (WTO, 2018). Although the freight cost accounted only for 3.6% of the total value of world trade, reducing transport cost is crucial since the optimum ship capacity can be determined by minimizing the cost of freight transport (Özen and Güler, 2001). In the early stages of the development of seaborne shipping, coal and oil were the major cargoes to transport. In 1950, the freight cost of coal from Northeastern America to Japan was about \$8 per tonne while the transport cost skyrocketed to \$32 per tonne after 56 years. During the nine market cycles during 1952-2004, the average transport cost of coal recorded \$12.30 per tonne with the highest \$44.80 per tonne and the lowest \$4.50 per tonne. However, the recent average freight cost has significantly dropped compared to the past transport cost. In 1960, the transport cost of Arabian light crude to European ports was about 30% percent of the price of a barrel in Arabian light oil, but in the last decade, the average transport cost was only 5% of from the past levels (Stopford, 2009).

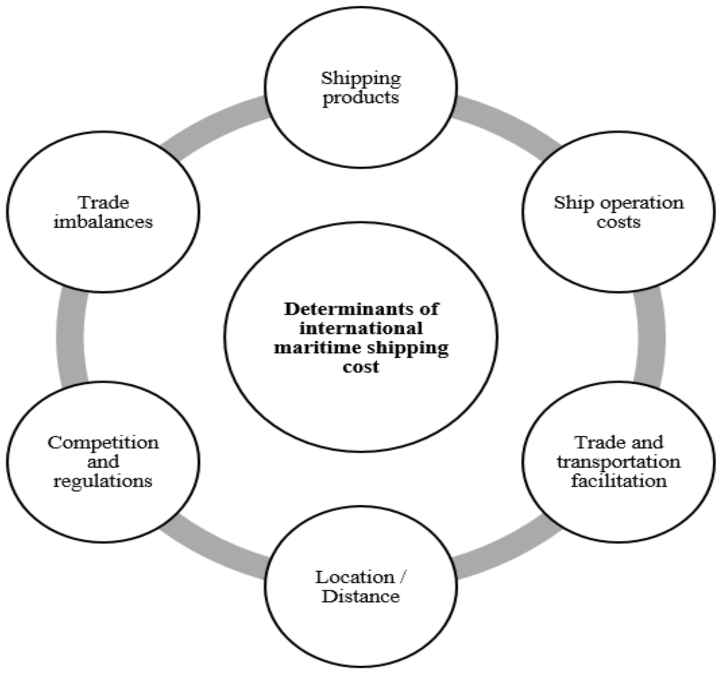
The significant decrease in the cost of freight transport is attributable to economies of scale, technology advancement, efficient ship operations and improved ports and infrastructure. Especially, economies of scale has played an important role of lowering the freight cost. The world merchant fleet of ships have different sizes and handle different cargo types, depths of water and hauling distances. In the fleet of tankers, VLCCs are able to handle over 200,000 dwt, whilst Suezmax, Aframax, Panamax, Handy ships and small tankers are able to load 120,001-199,999 dwt, 80,001-120,000 dwt, 60,001-80,000 dwt, 10,000-60,000 dwt and less than 10,000 dwt, respectively. VLCCs carry crude oil in long-hauls while Suezmax vessels transport the same item in medium-hauls (Kavussanos, 2010). Aframax ships tend to deliver petroleum products and Panamax ships carry either crude oil or products in extremely short-hauls. Handy ships not only handle petroleum products, but also transport chemicals (Chang and Chang, 2013). On the contrary, bulk carriers over 10,000 dwt include Capesize, Panamax, Handymax and Handy ships. Capesize vessels carry over 100,000 dwt while Panamax ships handle 60,001-99,999 dwt. Handymax ships deal with 40,001-60,000 dwt and Handy vessels transport 10,000-40,000 dwt. In particular, shipping companies became able to handle larger cargoes and parcels as the acceptable range of a tonnage through bulk carriers continuously increased. The average size of bulk ships recorded 34,000 dwt in 1981 and it increased to 56,000 dwt (Lebert, 2013). However, the average tanker size decreased in the early 2000s compared to 1981 as tanker shipping companies started providing more short-haul services than long-haul services recently (Oral, 2007).

Determinants of maritime transport costs have been extensively researched (Kumar and Hoffmann, 2002; Wilmsmeier et al., 2006; Cullinane, 2012; Sourdin and Pomfret, 2012; Wilmsmeier, 2014). <Fig.8> describes the determinants of international seaborne costs including ports, shipping products, facilitation, vessel operation costs, matter of location/distance within the international shipping network, competition and legal regulations in the seaborne industry and trade flows (Wilmsmeier, 2014). In order to improve the efficiency of the seaborne network, the role of port infrastructure is important as its performance is closely related to productivity of the industry. Shape and layout of the terminal, equipment, cranes, gate facilities, adequate yards and other factors influence on productivity. The factors are a system which is interconnected (Wilmsmeier et al., 2006). In sequence, the volume and the type of transported product are important factors as they influence on the elasticity of demand (Palander, 1935; Radelet and Sachs, 1998; Wilmsmeier, 2003; Wilmsmeier et al., 2006). The elasticity of demand is shortly the willingness to pay higher rates of shipowners (UNCTAD, 2015). Palander (1935) asserted that transport costs highly depend on the weight and value of the goods, transport modes and distance. There are two economies of scale in this aspect. The first economies of scale is internal that as the size of a single product increases, transport costs per tonne decreases. On the other hand, the external economies of scale explain that an increase in trade between two countries decreases transport costs (Winter, 1962).

Furthermore, trade and transportation facilitation affect transport cost as well. The easy accessibility of the decks in ports for vessels not only reduces waiting times, but also lowers trade costs. In the holding of cargo en route to the final destination, spending one more day at a port of call is the same as an ad valorem tariff of 0.6 to 2.1% (Hummels and Schaur, 2013). Besides, 10% of reduction in waiting times can reduce 0.5% of the maritime shipping cost (Wilmsmeier et al. 2006). Vessel operating costs is another determination of the cost of the freight transport. The maritime industry has achieved the reduction of the fright transport cost with high fuel efficiency, automated and modernized operation systems in seaports and economies of scales through technology advancement. Since oversupplied capacity has been serious in the seaborne industry due to slowdown in the global economy, improving efficiency and operations has been critical to deal with low freight rates. Position of a country and distance between ports are another two factors that affect the freight shipping cost. The international shipping network is composed of interconnected ports. Understandably, transporting cargoes and parcels in a long-haul requires more time and fuel. Time increase capital costs while fuel increases operating costs (UNCTAD, 2015). It was an established theory that two countries which are distant from each other tend to trade less (Tinbergen, 1962; Linnemann, 1966). Despite the conventional theory, the freight cost cannot alone be explained only by distance these days. The position of a country within the seaborne network is more important than the geographical distance (Kumar and Hoffmann, 2002; Angeloudis et al., 2006).

As well, competition and legal regulations in the maritime shipping industry is another factor which impacts on the freight shipping cost. Logistics markets tend to be very sensitive with price-setting due to the level of effective competition (Meersman et al., 2014). Competition is not only influenced by the size of markets, but also affected by legal regulations. Shipping lines have attempted to agglomerate through specialized activities with other market players to earn benefits of economies (Talley, 2009; UNCTAD, 2016). This effort has influenced on both the structure of the seaborne industry and the level of integration of in the international maritime shipping network (UNCTAD, 2015). In addition, policymakers tend to focus on observing the concentration activities to detect negative impacts on exports of a nation (Grzelakowski, 2013). Lastly, the cost of freight transport depends on trade flows. Trade flows can be describe as trade imbalances that the cost of bulk shipping on a full carrier in one direction is much higher than on a ship having spare capacity in return (Tomer and Kane, 2015). For example, the capacity of a bulk ship exporting from China to the U.S. is often full with cargoes and shipping companies are willing to transport at higher freight rates (UNCTAD, 2016). However, when the bulk ship returns from the U.S. to China, the vessel is almost empty. Thus, shipping companies are willing to carry the cargoes at much lower freight rate than when the ship is full of capacity (Davies, 1986; Behrens and Picard, 2008; Lun et al., 2010).

<Fig.5> Determinants of a seaborne shipping cost



Source: Reorganized Wilmsmeier (2014)

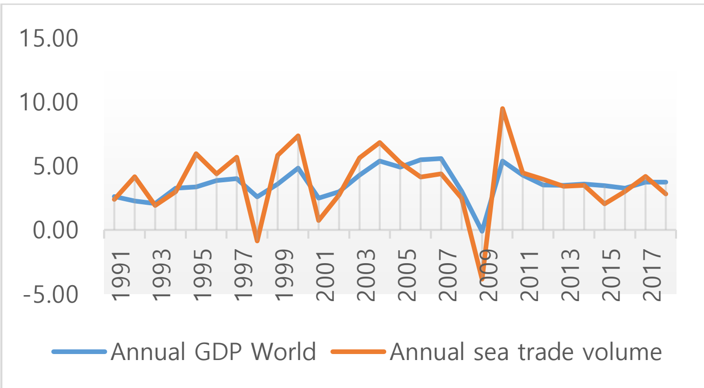
3.2 Shipping economics

3.2.1 Demand, supply and price

(1) *Demand*

The demand for the maritime transport is mainly influenced by the world economy, the volume of world seaborne trade, average haul, random economic/political shocks and transport cost. Firstly, the world economy produces most of the demand for the maritime transport. In order to forecast the future demand, it is important to have the historical data of world economic growth. <Fig.7> clearly illustrates that the growth of ocean trade and

<Fig.6> Annual growth in world GDP and seaborne trade volume: 1991-2018 (%)

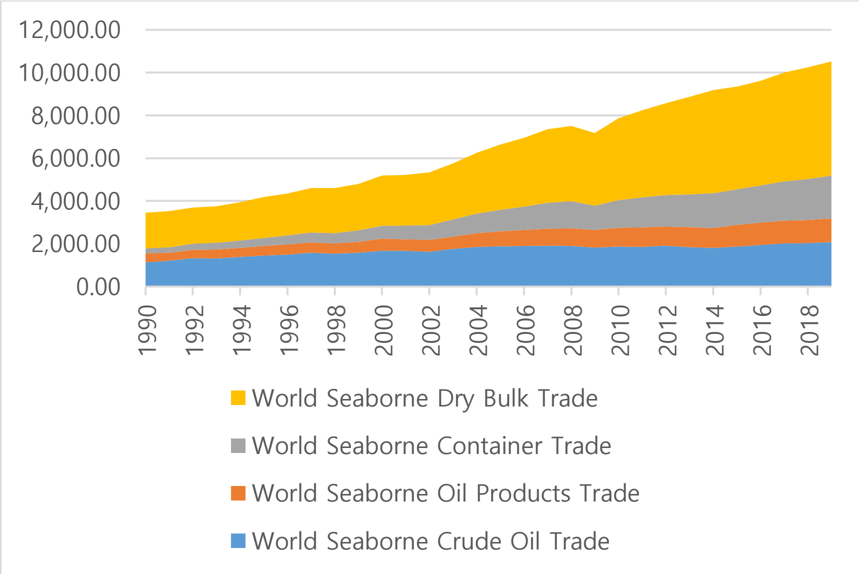


Source: Clarksons Research

the world economy tend to co-move in which sea trade sensitively responses to changes in the world GDP. However, the relationship between the world economy and ocean trade is far more complex (Stopford, 2009). Especially, a downturn or an upturn of the business cycle in the industry has the greatest effect on the demand for world seaborne trade. Especially, the slumps of the seaborne industry in 1975, 1983, 1989-1992 and 1998 synchronized with the downturns in the world economy (Vidučić et al., 2017). The causes of the recessions in the economic cycles are found to be many external and internal factors (Stopford, 2009). The external factors include random shocks such as macroeconomic crises and international affairs have significantly influenced on ship demand. Random shocks often stimulate the world economic system and cause fluctuations in commodity prices. Thus, it can be concluded that anticipated macroeconomic developments forecast the future shipping market conditions, which impact on the outcome of the negotiations between shipowners and charterers regarding present freight rates (Karakitsos and Varnavides, 2014).

The volume of world seaborne trade is another key factor which influences on the demand for shipping services. However, seaborne commodity trades should be discussed into two terms: short-term and long-term (Stopford, 2009). A short-term volatility is mainly caused by seasonality of some commodities (Lun et al., 2010). Particularly, agricultural commodities such as grains and fruits have the crown of the year during September-October (Rahn, 1968). As grain exports reach the peak from autumn to winter, demand for oil increases (Stopford, 2009). Since it is such a difficult task to plan transport of seasonal products in advance, shippers rely on spot charter rates to transport demand (Jiang et al., 1999). Spot markets are for short-term contracts for voyage within three months in duration (Ringheim and Stenslet, 2017). Also, short-term time charters ensures flexibility in responding to changes in market developments (Axarloglou et al., 2013). Long-term trends in commodity trade can be well identified by understanding the characteristics of the industry where commodities are produced and consumed (Stopford, 2009). The characteristics include shifts in demand for particular products, shifts of sources where commodities are detracted from and shifts in process due to the relocation of a plant which affects the trading pattern (Lun et al., 2010). Especially, the trade of crude oil clearly illustrates the shifts in demand that the demand for crude oil during the 1970s had fallen due to the increase in oil prices and the crude oil market had entered a stagnation then experienced a recession (Kutasovic, 2012). <Fig.8> describes the world seaborne trade by type of commodity from 1990 to 2018.

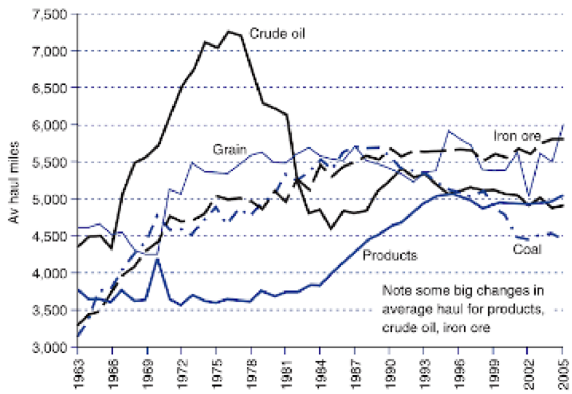
<Fig.7> **World seaborne trade by type of cargo: 1990-2018 (million tonnes)**



Source: Clarksons Research

Average haul is another key factor that impacts on demand for sea transport. Sea transport not only depend on the volume of trade, but also require time for commodities to be shipped (Notteboom, 2006). Since time depends on distance, transporting the same amount of tonnage from Korea to Canada takes more time than from Korea to Japan. Depending on time it takes to reach the destination, distance can be divided into short- or long-hauls (Simcock, 2016). The term ‘ton-miles’ can be calculated through the multiplication of the tonnage of cargo shipped and the average distance from an outport to a port of unloading (Stopford, 2013). Interestingly, random shocks have played an important role of affecting average haul. For instance, the recent closure of the Suez Canal has increased the average distances which merchant ships have traveled (Sichko, 2011).

<Fig.8> Average distance of seaborne trades by commodity: 1963-2005



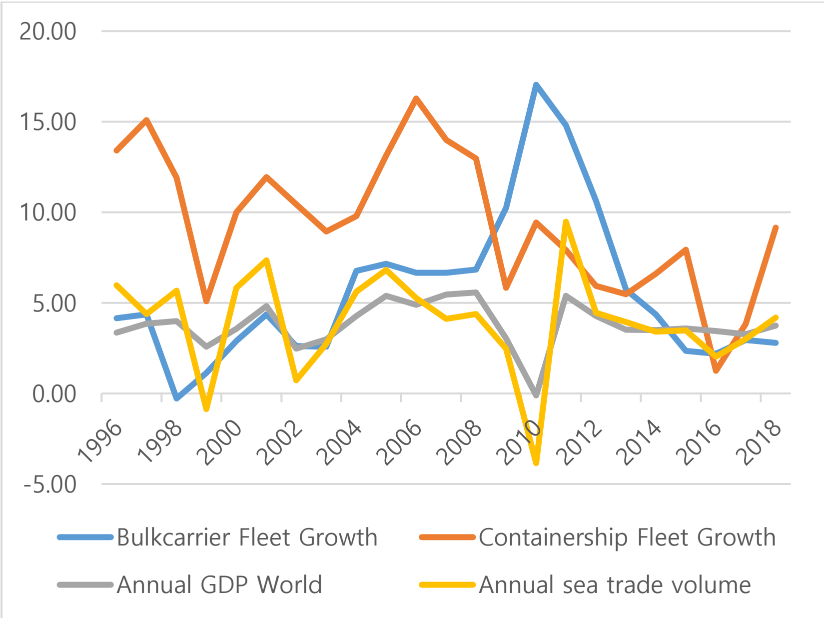
Source: Stopford (2009), p.147

(2) *Supply*

The four decision makers, shipowners, shippers, banks, and regulatory institutions, control the supply side of shipping services (Stopford, 2013). Shipowners increase or decrease supply of ships by ordering new vessels, scrapping old ships, deciding the time when to move fleet into lay-up depending on demand for shipping services while shippers issue time charters (Stopford, 2009). Bankers finance in shipping and forces weak shipping companies to close their businesses (Lorange, 2009). Regulatory stakeholders also affect capacity of the fleet of ships by establishing economic and environmental legislation (Vuori, 2013).

The supply of capacity explains the supply side of maritime transport that available tonnage for transporting cargoes from a port to another port by ocean. Except untradeable ships, trading ships can be defined as 'active transport supply' (Lun et al., 2010). Untradeable ships are often called 'laid-up tonnage', 'available transport supply' (Lun et al., 2010). Thus, total supply of tonnage is the sum of 'active transport supply' and 'available transport supply' (Lun et al., 2010). The key feature in the supply mechanism of the seaborne industry is that shipowners adjust the supply of tonnage when expected demand for shipping services turns out to be low. <Fig.10> clearly illustrates that the supply of capacity was adjusted to the decline in world GDP through 1996-2018. For example, in the early 1960s, the growth rate of tanker fleet went through a boom cycle. However, the tanker fleet could not keep with up with increasing demand for crude shipping services and the tanker market experienced a shortage of supply (Abouarghoub et al., 2012). Furthermore, the price of tanker ships during the shortage was twice the contract price (Dimitriou, 2016). However, tanker demand significantly fell by more than 50% in the mid-1970s and the supply of capacity exceeded demand (Blaalid and Backer, 2016). To recover the imbalance, it took almost ten years for supply to adjust to a shift in demand (Stopford, 2009). Despite the market collapse due to the oil crisis in 1973, the fleet of tanker ships kept rising and the supply of capacity due to the deliveries on orders made before 1973 (Dimitriou, 2016). Scrapping did not start off until the price of second-hand of VLCCs which cost $55 million in average when built, fell below $3 million (Clarkson Research, 2018).

<Fig.9> Annual percentage growth of bulk fleet, container-ship fleet, world GDP and seaborne trade volume: 1996-2018 (%)



Source: Clarksons Research

The maritime industry is composed of four markets including newbuilding market, freight market, second-hand market and demolition market (Abouarghoub et al., 2012). In particular, the roles of newbuilding and demolition markets are highlighted. Firstly, the newbuilding or shipbuilding market plays an active role in adjusting supply of fleet. Adjustments of newbuilding output do not quickly occur. In practice, shipbuilding output in 1996 had decreased from 12% to 5% in 22 years, and it took another 11 years to back up to the level of 9%. This clearly illustrates that a newbuilding activity has a long-run cycle, Also, the time-lag exists in the shipbuilding market which explains the duration between order and delivery tends to be one and four years (Stopford, 2009).

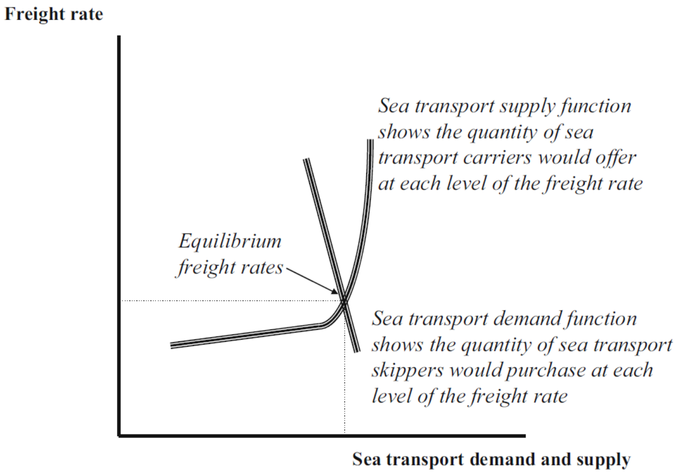
Secondly, merchant fleet depends on adjustments in demolition market as well. The main activity of the demolition market is to scrap old ships. In deciding whether remove ships or not, the demolition market considers age of a ship, scrapping price and market prospects (Adland, 2010). Age is the basic factor which the market considers as repair and maintenance costs are proportional to age of a ship. The scrap prices play crucial role in the demolition market as they are highly volatile depending on the status of supply and demand in the steel industry (Karlis, 2016). Scrapping decisions made by shipowners, shippers and other stakeholders in the maritime shipping industry highly depend on the market expectations (Khalid, 2012). This is because market forecasts are the criteria which provides information of the future operating profitability. Shipowners will not sell an unprofitable vessel during a decline in the industry because there is a light chance of having a boom near future (Stopford, 2009). Scrapping is active only when cash reserves are enough and the market future is sanguine (Seetharam, 1993; Stopford, 2013).

(3) *Prices (or freight rates)*

The last part of maritime shipping market model is the freight market. The market is based on the adjustment mechanism which links supply and demand. A freight rate is an outcome of a negotiation between shipowners and charterers which reflects the balance of vessels and cargoes available in the market (Stopford, 2009). A freight rate tends to be high when ships are mostly in active transport supply, on the contrary, a freight rate falls when available transport supply is high (Lun et al., 2010). Once a freight rate is recognized, shipowners and charterers adjust the freight rate to balance supply and demand (Jugović et al., 2015).

<Fig.11> describes the freight rate mechanism in a pefectly competitive market. Numerous literature have reached an agreement that the freight rate system in the seaborne freight market is an adjustment mechanism which interrelates supply and demand. The supply function is in the form of J-shaped curve, describing that shipowners adjust the amount of transport services depending on the level of freight rates in the short-run and minimizes operating costs in the long-run. On the contrary, the demand curve is nearly vertical and the demand function illustrates how charterers adjust to the shifts in price (Stopford, 2009; Jugović et al., 2015). Ultimately, buyers and sellers will find an equilibrium price at the intersection of supply and demand curves.

<Fig. 10> The freight rate mechanism



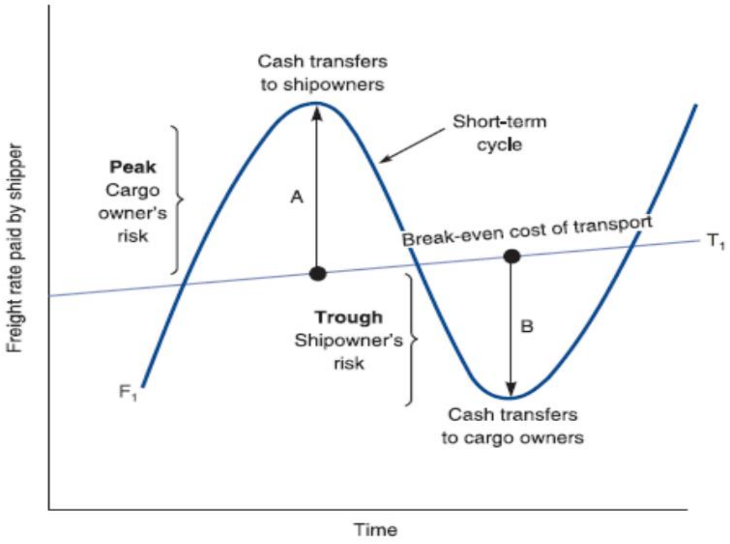
Source: Lun et al. (2010), p.28

3.2.2 Shipping cycles

The risk of seaborne investment can be managed through observation of shipping cycles (Lun et al., 2010). As ships are the equipment which cost high, investing in shipping is capital-intensive. Since the volume of trade is one of the factors which determines the return on investment in ships, it is important to analyze how the supply of ships fluctuates to an imbalance between investment and the volume of trade. Shipping businesses will temporarily discontinue operating due to the shortage of ships when the volume of trade grows while the investment in ships does not take place. On the other hand, if ships are invested while there is no growth of the volume of trade, the laid-up of ships will be oversupplied. Cargo owners will take this shipping risk when the volume of trade is expected to be in great demand in the future (Jugović et al., 2015). However, some shipowners are not risk averse. As an economic concept, shipping cycle can be defined as the mechanism of how shipping companies and freight rates respond to changes in the supply of and demand for ships (Karakitsos and Varnavides, 2014).

The characteristics of shipping cycles have been studied by many researchers and the conclusion has reached that a shipping cycle is a complex consequence of the market mechanism that weak shipping companies face to the cessation of business while strong shipping companies continue running the businesses and being prosperous (Kirkaldy, 1914; Lun et al., 2010). The first stage in a typical shipping market cycle is a trough which implies the meaning of a shortage of ships (Fayle, 1933; Stopford, 2009). An increase in freight rates causes excessive newbuilding orders. These exceeded orders lead to the state of oversupply of ships and the shipping cycle enters a collapse. In short, the mechanism of shipping cycle illustrates balancing the supply of and demand for vessels. An excessive demand for ships increases a freight rate until more ships are built while an excessive supply of ships causes a decline in the freight rate until ships are obsolete (Lun et al., 2010). Hence, the mechanism which drives the shipping cycle is based on the competitive process occurring from the interaction between supply and demand to determine a freight rate (Stopford, 2009; Lun et al., 2010). [Table 5] describes each stage of the shipping cycle while <Fig.6> illustrates a typical shipping market cycle.

<Fig.11> A typical shipping market cycle



Source: Stopford (2009), p.102

[Table 6] Stages in the shipping cycle

Stages	Characteristics
(1) Trough	- Shipping capacity is in the state of surplus with ships standing at loading points and ships are slow steaming. - Freight rates fall below the operating cost of the least attractive ships. The least efficient ships enter on laying up. - Low freight rates and tight credit cause negative cash flow and a demolition market become active.
(2) Recovery	- Freight rates increase to the level operating costs and laid up capacity begins falling as supply and demand are adjusted toward balance. However, market uncertainty is still rampant. - The prices of second-hand increase as liquidity improves.
(3) Peak	- Only inefficient ships are laid up since most ships are in operation at a maximum operational speed. - Freight rates tend to double or triple the operating costs, or sometimes as much as ten times. - Supply is almost equal with demand. High freight rates generate high earnings, and consequently, improve liquidity. - Newbuilding orders increase. However, a peak ultimately leads to overtrading as second-hand prices rise much above their replacement costs, and new vessels are sold at higher costs than newbuilding price.
(4) Collapse	- The market enters a collapse as supply exceeds demand and freight rates decline quickly. Trading ships begin reducing speed to save fuel. - An economic shock tends to reinforce a downturn in the business cycle and cause accumulations of containers and fleet in ports. - Liquidity is still high though and shipowners reject to sell their ships at a lower price.

Source: Restructured from Stopford (2009)

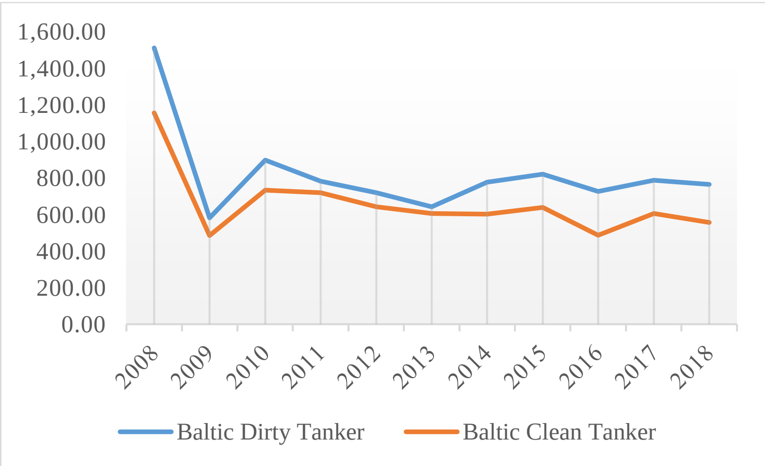
3.3 The Seaborne shipping markets

3.3.1 The tanker market

Recently, heavy oil consumption in Asia Pacific countries such as China and India have driven the growth of global oil trade (International Energy Agency, 2015). Not only because of lower crude prices compared to the historical prices, but China has also planned to excessively expand its refinery and petroleum reserve capacity. Besides, India has become an emerging oil importer (Clarkson Research, 2015). While Asia Pacific has become the top oil consumer in the world, crude imports for the U.S. has continuously decreased due to its shale gas production. On the export side, African crude exports declined by 5% in 2014 compared to 2013 due to conflicts in Libya and technical issues in Angola and Nigeria (UNCTAD, 2015). Petroleum product imports also have positively impact on the growth of tanker trade that emerging areas such as South America and Asia Pacific have increased the volume of petroleum products by 2% in 2014 compared to the previous year. Natural gas and liquefied gas trade has increased as well. The volume of gas trade for the biggest consumer of gas, Japan, increased while of Korea, the second largest importer, decreased by 6% (UNCTAD, 2015). Lastly, global LNG consumption has significantly increased and this has continuously driven the growth of demand for LNG transport services.

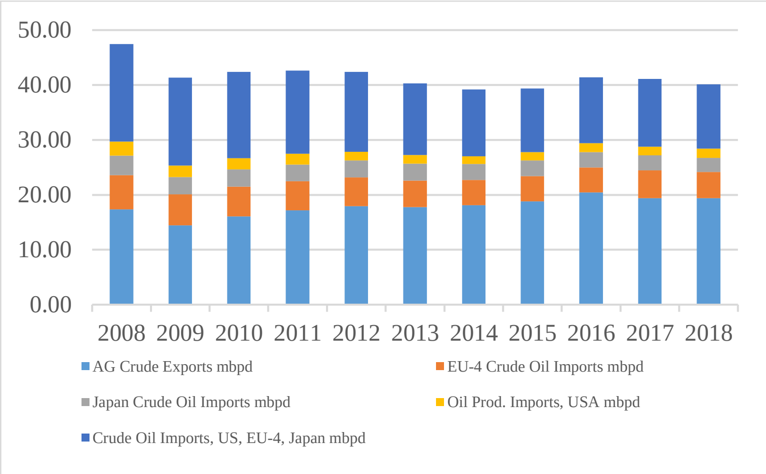
In 2017, the tanker market went through a challenging year due to continuous growth in supply of fleet especially in the crude sector. The annual growth of demand for oil trade recorded 3% while the size of crude oil tanker increased by 5.0% and the size of petroleum product tanker grew by 4.2% (Clarksons Research). The imbalance between rapid growth in the supply of tanker fleet transporting crude oil and petroleum products and relatively slow growth of demand for tanker trade caused the state of a weak over-supply of capacity. Thus, in 2017, the Baltic dirty tanker and clean tanker indices failed to back up to the levels of 2015. In addition, the freight rates of crude oil and petroleum products shipping and freight earnings remained weak as well. The causes of continuous growth in the supply of fleet are found to be increase in demand for crudes and products within Asia Pacific region and steady growth in South America. Furthermore, demolishing activities increased in the tanker market due to poor market conditions.

<Fig. 12> Baltic tanker indices: 2008-2018 (point)



Source: Clarksons Research

<Fig. 13> **World crude oil and products trade: 2008-2018 (mbpd)**

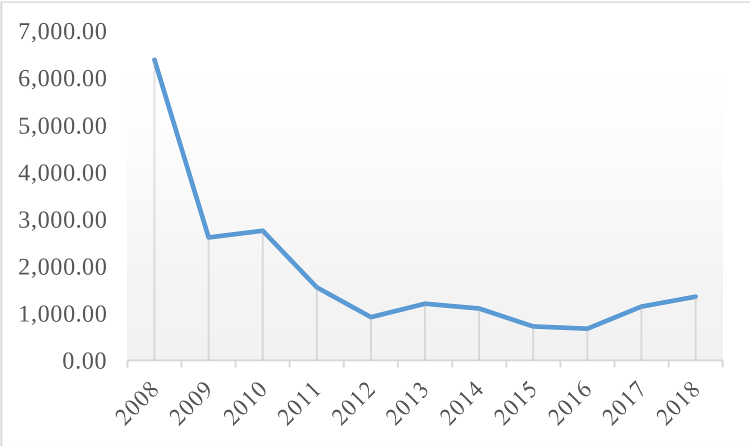


Source: Clarksons Research

3.3.2 The dry bulk market

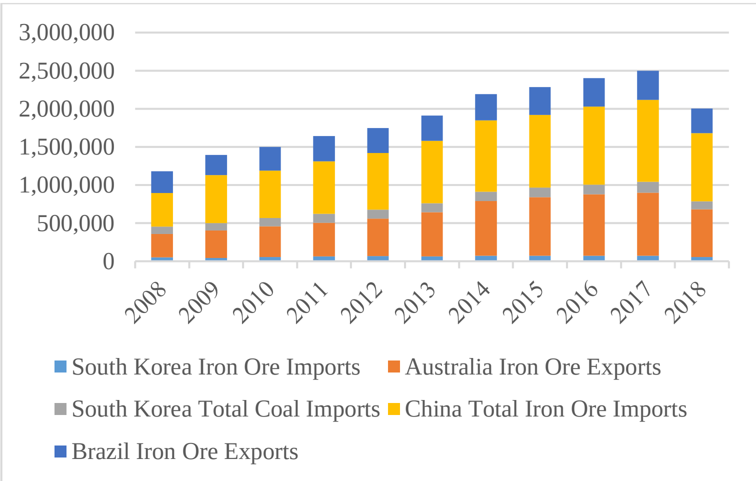
Compared to the tanker market, the dry bulk market successfully recovered its demand for maritime shipping trade. The growth rate in demand for seaborne bulk trade exceeded the growth rate in supply for tonnage in 2017 as demand for bulk cargoes increased while the supply of fleet continuously fell. The demand for maritime bulk shipping trade grew by 4.4% in 2017 compared to 2.0% in 2016. However, the growth in supply for fleet recorded 3.0%. The BDI has continuously rebounded consecutively for two years from 2016 to 2018. Although the BDI failed to reach the highest level of 2,178 points in 2013, the BDI stood at 1,619 points in December 2017. Consequently, average earnings also increased due to the recovery on the market conditions. Improvement in the Capesize market in 2017 was driven by growth in demand for the iron ore and coal imports for China. In addition, the level of supply fleet was curbed by the growth, and freight rates increased as it can be seen in <Fig.17> (UNCTAD, 2018). Other freight markets in the bulk shipping such as the Panamax, Handysize and Supramax markets were also substantially improved under similar conditions to the Capesize market.

<Fig. 14> Baltic Dry Index: 2008-2018 (point)



Source: Clarksons Research

<Fig. 15> World dry bulk trade: 2008-2018 (Thousand tonnes)

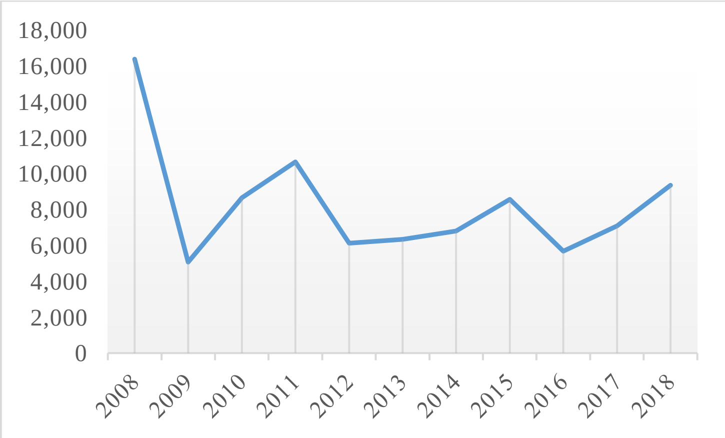


Source: Clarksons Research

3.3.3 The container market

Despite challenging market conditions in 2016, the world container trade substantially grew by 6.4% in 2017 than the previous year. It can be analyzed that an expansion in demand for global container trade improved the container market conditions which were worsened by the 2016 financial crisis. On the other hand, global supply of container fleet increased by 2.8% in 2017 which equals with 256 million dwt. Although the supply growth was moderate in 2017, it is expected that the supply of container capacity will increase by 3% in 2018. Thus, the substantial expansion in demand for the global container trade and the moderate growth of supply positively impacted on freights rates of the container market that freight rates also recovered from the levels of during the economic shock in 2016. <Fig.20> clearly illustrates that earnings on container seaborne shipping have continuously increased since 2016. Especially, spot freight rates significantly shifted in 2017. Average spot freight rates on the shipping route between China and the Western U.S. rose by 17.3% ($1,485 per 40-foot equivalent unit) and on the mainline route China and Southern Europe expanded by 19.4% ($817 per TEU) in the year (UNCTAD, 2018). Furthermore, intra-Asian container trade also drove an increase in freight rate. For instance, the spot rate between Shanghai-Singapore lines rose by 111%. It is proved that the rapid growth of Chinese economy and emerging countries the main cause of these remarkable recovery of the container market.

<Fig. 16> Clarksons Containership Earnings Index: 2008-2018 ($/day)



Source: Clarksons Research

<Fig. 17> World container trade: 2008-2017 (million TEU)

Source: Clarksons Research

[Table 7] The world seaborne fleet at January 1st, 2007 (million dwt)

	Size of fleet				Annual percentage growth		
	1980	1990	2000	2007	1980-90	1990-00	2000-07
Bulk	140.7	203.4	266.8	369.7	4%	3%	5%
Tankers	339.3	262.9	307.0	363.9	-3%	2%	2%
Combined	47.4	30.3	14.9	9.4	-4%	-7%	-6%
Container	9.9	26.3	64.7	128.0	10%	9%	10%

Sources: Clarksons Research, Stopford (2009)

Chapter 4. Empirical analysis

4.1 Data

This study used 28 monthly time series of demand, supply, and freight rates in the tanker, the dry bulk and the container markets. The data used in this study were sourced from the Clarksons Research[1]. The study period of the time series related to the tanker and the dry bulk markets are the same as 2004:05-2018:03. However, due to the shortage of data, the study period of the container-related time series is 2009:12-2018:03. This study chose the period as steel production of China grew by 325% (144 million tons a year to 468 million tons a year) between 2003 and 2008 (Stopford, 2009). Also, Korea, China, Europe, and Japan increased the supply of overall fleet in the same period. Furthermore, although the demand for oil trade grew between 2003 and 2004, the tanker market experienced a shortage of supply. This shortage in supply of fleet led to the rise of the tanker and the bulk freight rates. This study also encompasses the periods of recession including the financial crisis in 2008 due to the subprime mortgage crisis and overall recovery in demand for international trade in the last few years. The detailed descriptions of time series are sorted by type of market with individual sections of demand (the volume of trade), supply (fleet development) and prices (freight rates).

[1] Clarksons Research is a provider of intelligence for international shipping including offshore and energy, shipping and trade and valuations to financial environment. Time series of the shipping markets are available from this source.

4.1.1 Tanker market

4.1.1.1 Demand

This study used four time series including U.S crude oil imports, China crude oil imports, India crude oil imports and U.S. oil product exports during 2004:05-2018:03 for demand in the tanker market. These data were obtained from the Clarksons Research. The data for demand in tanker market and descriptive statistics are illustrated in [Table 8] and [Table 9], respectively.

(1) The volume of commodity trade

[Table 8] Data for demand in tanker market

Variable	Unit	Period	Frequency	Source
U.S. crude oil imports	mbpd[2]	2004:05-2018:03	Monthly	Clarksons Research
China crude oil imports	mbpd	2004:05-2018:03	Monthly	Clarksons Research
India crude oil imports	mbpd	2004:05-2018:03	Monthly	Clarksons Research
U.S oil product exports	mbpd	2004:05-2018:03	Monthly	Clarksons Research

[2] "Thousand barrels per day" (mpbd) is a unit of measurement of crudes and oil products on a daily basis (Rusco, 2011).

[Table 9] Descriptive statistics

Variable	Size	Mean	Std. Dev.	Min	Max
U.S. crude oil imports	167	6.46	1.65	3.89	9.06
China crude oil imports	167	3.16	0.86	1.65	4.78
India crude oil imports	167	4.61	1.76	1.70	8.67
U.S oil product exports	167	1.92	0.88	0.46	3.60

(2) Supply

This research used two time series including small tankers fleet development and crude Aframax fleet growth rate during 2004:05-2018:03 for supply of fleet in the tanker market. These data were sourced from the Clarksons Research. The data for supply in tanker market and descriptive statistics are illustrated in [Table 10] and [Table 11], respectively.

4.1.1.1.2 Fleet development

[Table 10] Data for supply in tanker market

Variable	Unit	Period	Frequency	Source
Small tankers fleet development	Number	2004:05-2018:03	Monthly	Clarksons Research
Crude Aframax fleet growth rate	%	2004:05-2018:03	Monthly	Clarksons Research

[Table 11] Descriptive statistics

Variable	Size	Mean	Std. Dev.	Min	Max
Small tankers fleet development	167	2533.67	360.26	1919.00	3044.00
Crude Aframax fleet growth rate	167	2.81	2.91	-3.12	7.88

4.1.1.3 Price

This study used two time series including 1-year time charter rates for oil products (medium range) and 1-year time charter rates for 150,000 dwt during 2004:05-2018:03 for price in the tanker market. These data were obtained from the Clarksons Research. The data for price in tanker market and descriptive statistics are illustrated in [Table 12] and [Table 13], respectively.

4.1.1.3.1 Time charter freight rates

[Table 12] Data for price in tanker market

Variable	Unit	Period	Frequency	Source
1-year time charter rates for oil products (medium range)	$/day	2004:05-2018:03	Monthly	Clarksons Research

1-year time charter rates for 150,000 dwt	$/day	2004:05-2018:03	Monthly	Clarksons Research
1-year time charter rates for 47-48,000 dwt	$/day	2004:05-2018:03	Monthly	Clarksons Research
1-year time charter rates for 37,000 dwt	$/day	2004:05-2018:03	Monthly	Clarksons Research
3-year time charter rates for 150,000 dwt	$/day	2004:05-2018:03	Monthly	Clarksons Research

[Table 13] Descriptive statistics

Variable	Size	Mean	Std. Dev.	Min	Max
1-year time charter rates for oil products (medium range)	167	17988.44	5471.92	12000.00	30500.00
1-year time charter rates for 150,000 dwt	167	30760.99	11776.91	15246.00	58750.00
1-year time charter rates for 47-48,000 dwt	167	17988.44	5471.92	12000.00	30500.00
1-year time charter rates for 37,000 dwt	167	16303.15	5043.02	10000.00	27250.00
3-year time charter rates for 150,000 dwt	167	29222.57	7422.33	17000.00	45000.00

4.1.2 Dry bulk market

4.1.2.1 Demand

This research used four time series including China seaborne steam coal exports, China seaborne iron ore imports, Ukraine iron exports, and Russian iron ore imports during 2004:05-2018:03 for demand in the dry bulk market. These data were sourced from the Clarksons Research. The data for supply in dry bulk market and descriptive statistics are illustrated in [Table 14] and [Table 15], respectively.

4.1.2.1.1 The volume of commodity trade

[Table 14] Data for demand in dry bulk market

Variable	Unit	Period	Frequency	Source
China seaborne steam coal exports	thousand tonnes	2004:05-2018:03	Monthly	Clarksons Research
China seaborne iron ore imports	million tonnes	2004:05-2018:03	Monthly	Clarksons Research
Ukraine iron exports	thousand tonnes	2004:05-2018:03	Monthly	Clarksons Research
Russian iron ore imports	thousand tonnes	2004:05-2018:03	Monthly	Clarksons Research

[Table 15] Descriptive statistics

Variable	Size	Mean	Std. Dev.	Min	Max
China seaborne steam coal exports	167	1826.12	2061.70	0.00	7475.00
China seaborne iron ore imports	167	54.65	23.32	12.99	101.25
Ukraine iron exports	167	2607.20	801.87	951.00	4449.00
Russian iron ore imports	167	2798.311	1563.01	851.00	7328.00

4.1.2.2 Supply

This study used two time series including total bulk carrier fleet development and bulk carrier fleet growth rate during 2004:05-2018:03 for supply of fleet in the dry bulk market. These data were obtained from the Clarksons Research. The data for price in dry bulk market and descriptive statistics are illustrated in [Table 16] and [Table 17], respectively.

4.1.2.2.1 Fleet development

[Table 16] Data for supply in dry bulk market

Variable	Unit	Period	Frequency	Source
Total bulk carrier fleet development	Number	2004:05-2018:03	Monthly	Clarksons Research
Bulk carrier fleet growth rate	%	2004:05-2018:03	Monthly	Clarksons Research

[Table 17] Descriptive statistics

Variable	Size	Mean	Std. Dev.	Min	Max
Total bulk carrier fleet development	167	8525.44	1903.81	5669.00	11170.00
Bulk carrier fleet growth rate	167	7.50	4.30	1.91	17.60

4.1.2.3 Price

This research used three time series including 6-month time charter rates for 75,000 dwt, 1-year time charter rates for 75,000 dwt and 3-year time charter rates for 75,000 dwt during 2004:05-2018:03 for price in the dry bulk market. These data were sourced from the Clarksons Research. The data for prices in dry bulk market and descriptive statistics are illustrated in [Table 18] and [Table 19], respectively.

4.1.2.3.1 Time charter freight rates

[Table 18] Data for price in dry bulk market

Variable	Unit	Period	Frequency	Source
6-month time charter rates for 75,000 dwt	$/day	2004:05-2018:03	Monthly	Clarksons Research
1-year time charter rates for 75,000 dwt	$/day	2004:05-2018:03	Monthly	Clarksons Research
3-year time charter rates for 75,000 dwt	$/day	2004:05-2018:03	Monthly	Clarksons Research

[Table 19] Descriptive statistics

Variable	Size	Mean	Std. Dev.	Min	Max
6-month time charter rates for 75,000 dwt	167	23092.78	19109.52	4675.00	89000.00
1-year time charter rates for 75,000 dwt	167	21067.96	17501.07	4781.00	79375.00
3-year time charter rates for 75,000 dwt	167	17764.29	12382.44	6194.00	63400.00

4.1.3 Container market

4.1.3.1 Demand

This study used two time series including China seaborne containerized imports and Asia-Europe container trade growth rate during 2009:12-2018:03 for demand in the container-ship market. These data were obtained from the Clarksons Research. The data for demand in dry bulk market and descriptive statistics are illustrated in [Table 20] and [Table 21], respectively.

4.1.3.1.1 The volume of commodity trade

[Table 20] Data for demand in container market

Variable	Unit	Period	Frequency	Source
China seaborne containerized imports	million tonnes	2009:12-2018:03	Monthly	Clarksons Research
Asia-Europe container trade growth rate	%	2009:12-2018:03	Monthly	Clarksons Research

[Table 21] Descriptive statistics

Variable	Size	Mean	Std. Dev.	Min	Max
China seaborne containerized imports	100	9.36	1.16	6.00	11.89
Asia-Europe container trade growth rate	100	4.45	10.46	-21.78	52.90

4.1.3.2 Supply

This research used two time series including total container ships fleet development and total container charter owner fleet development during 2009:12-2018:03 for supply of fleet in the container-ship market. These data were sourced from the Clarksons Research. The data for supply in dry bulk market and descriptive statistics are illustrated in [Table 22] and [Table 23], respectively.

4.1.3.2.1 Fleet development

[Table 22] Data for supply in container market

Variable	Unit	Period	Frequency	Source
Total container ships fleet development	Number	2009:12-2018:03	Monthly	Clarksons Research
Total container charter owner fleet development	Number	2009:12-2018:03	Monthly	Clarksons Research

[Table 23] Descriptive statistics

Variable	Size	Mean	Std. Dev.	Min	Max
Total container ships fleet development	100	5084.09	99.52	4804.00	5225.00
Total container charter owner fleet development	100	2690.15	103.31	2446.00	2834.00

4.1.3.3 Price

This study used two time series including SCFI[3] Shanghai-Durban freight rates, SCFI Shanghai-Mediterranean freight rates, SCFI Shanghai-West U.S. freight rates and SCFI Shanghai-Europe freight rates during 2009:12-2018:03 for prices in the container-ship market. These data were obtained from the Clarksons Research. The data for prices in container market and descriptive statistics are illustrated in [Table 24] and [Table 25], respectively.

4.1.3.3.1 Freight rates

[Table 24] Data for price in container market

Variable	Unit	Period	Frequency	Source
SCFI Shanghai-Durban freight rates	$/TEU	2009:12-2018:03	Monthly	Clarksons Research
SCFI Shanghai-Mediterranean freight rates	$/TEU	2009:12-2018:03	Monthly	Clarksons Research
SCFI Shanghai-West U.S. freight rates	$/TEU	2009:12-2018:03	Monthly	Clarksons Research
SCFI Shanghai-Europe freight rates	$/TEU	2009:12-2018:03	Monthly	Clarksons Research

[3] Shanghai Containerized Freight Index (SCFI) is an economic transport shipping index which reflects spot rates of 15 ocean shipping routes. SCFI limits its type of cargo to general dry cargo container and the freight rates in each route is an arithmetic mean of the freight rates for the 15 routes (Korea Customs Logistics Association).

[Table 25] Descriptive statistics

Variable	Size	Mean	Std. Dev.	Min	Max
SCFI Shanghai-Durban freight rates	100	953.86	313.56	325.40	1675.50
SCFI Shanghai-Mediterranean freight rates	100	1092.42	419.92	220.50	1958.75
SCFI Shanghai-West U.S. freight rates	100	1799.52	462.23	796.50	2801.80
SCFI Shanghai-Europe freight rates	100	1054.79	426.85	223.50	2075.00

4.2 Empirical results

4.2.1 Hypothesis I: Short-run or long-run equilibrium relationship exists among demand, supply and freight rates within a shipping market.

4.2.1.1 The tanker market

According to the empirical results for the Johansen (1991) cointegration tests on demand and price variables for the tanker market, the optimal lags between price (1-year time charter rate for medium range) and demand (U.S. crude imports and U.S. oil product exports) were the same as 3 months. When r = 1, trace statistics were analyzed to be less than 5% critical value thus the null hypothesis of having one or less cointegrating vector could not rejected. Hence, these results confirmed that there only one cointegrating vectors existed between demand and price.

On the other hand, the lags between China crude oil imports, India crude oil imports, U.S. oil product exports and small tanker fleet development were all 3 months. When r = 1, trace statistics were found to be less than 5% critical value and the null hypothesis of having one or less cointegrating vector was not rejected. Thus, it was analyzed that there was only one cointegrating vector between the variables.

Lastly, in the cointegration analysis of price and supply, supply (crude Aframax fleet growth) and price (1-year time charter rate for 150,000 dwt, 1-year time charter rate for 47-48,000 dwt, 1-year time charter rate for 37,000 dwt and 3-year time charter rate for 150,000 dwt) were cointegrated with the lags of 3 months, 2 months, 4 months and 4 months, respectively. Also the null hypothesis was not rejected as trace statistics did not reach 5% critical value.

By observing a coefficient of ECT_{t-1}, the speed of adjustment to the equilibrium when there is a drift from the long-run equilibrium at $t-1$ can be found. An ECT from the cointegration equation between and demand (U.S. crude oil imports) and price (1-year charter rate for medium range) is in Eq. (4.1). Eq. (4.1) indicates that demand (U.S. crude oil imports) and price (1-year charter rate for medium range) is in the positive long-run relation.

$$Demand_{t-1} = 1.559 + 0.0002 * Price_{t-1} + ECT_{t-1} \qquad (4.1)$$

The long-term and the short-run causality among demand, supply, and prices in the tanker market, and the causality coefficients are described in [Table 28], [Table 31] and [Table 34]. The results indicate that there long-term bidirectional causality exist between demand (U.S. oil product exports) and price (1-year time charter rate for medium range) with the coefficients of 827.62 (demand to price) at 5% significance level and -0.121 (price to demand) at 1% significance level. These results of strong Granger causality support that changes in demand highly influence on changes in price in the tanker market.

4.2.1.1.1 Demand – Price

(1) Results for cointegration tests

[Table 26] Results for ADF and PP unit root tests

	Variables	ADF		PP		Result
		Levels	First differences	Levels	First differences	
Price	1-year time charter rates for products (medium range)	-1.063	-3.928	-1.361	-92.435	Level: $I(1)$ 1st Diff.: $I(0)$
Demand	U.S. crude oil imports	-1.546	-1.478	-3.488	-228.348	Level: $I(1)$ 1st Diff.: $I(0)$
	U.S. oil product exports	-1.499	-2.138	-1.478	-157.764	Level: $I(1)$ 1st Diff.: $I(0)$

Note 1) Critical value: ADF t-statistics 1% = -3.488, 5% = -2.886, 10% = -2.576; PP t-statistics: 1% = -20.017, 5% = -13.830, 10% = -11.087

[Table 27] Results for Johansen cointegration tests

Variables		H_0	Lag	λ_{trace}	Cointegration
1-year time charter rate (medium range)	U.S. crude oil imports	$r = 0$	3	5.7265	O
		$r \leq 1$		0.6042	
	U.S. oil product exports	$r = 0$	3	12.4078	O
		$r \leq 1$		1.0807	

Note 1) 5% critical value: r = 0, 15.41; r = 1, 3.76, 1% critical value: r = 0, 20.04; r = 1, 6.65

Note 2) The appropriate lag lengths were selected using Akaike's Information Criteria (AIC).

(2) Results for Granger causality tests

[Table 28] Results for Granger causality tests

Hypothesis	Long-run	Short-run	Strong
1-year time charter rate (medium range) ↛ U.S. crude oil imports	-0.034* (0.083)	0.000 (0.125)	5.92** (0.052)
U.S. crude oil imports ↛ 1-year time charter rate (medium range)	216.724* (0.068)	384.258 (0.426)	4.41 (0.111)
1-year time charter rate (medium range) ↛ U.S. product exports	-0.121*** (0.006)	0.000 (0.243)	8.33** (0.016)
U.S. oil product exports ↛ 1-year time charter rate (medium range)	827.624** (0.048)	377.560 (0.612)	5.16** (0.076)

4.2.1.1.2 Supply – Demand

(1) Results for cointegration tests

[Table 29] Results for ADF and PP unit root tests

	Variables	ADF		PP		Result
		Levels	First differences	Levels	First differences	
Supply	Small tanker fleet development	-2.433	-9.739	-0.501	-146.378	Level: $I(1)$ 1st Diff.: $I(0)$
Demand	China crude oil imports	-2.242	-26.233	-3.416	-238.600	Level: $I(1)$ 1st Diff.: $I(0)$
	India crude oil imports	-2.263	-21.825	-4.230	-212.608	Level: $I(1)$ 1st Diff.: $I(0)$
	U.S. oil product exports	-1.499	-2.138	-1.478	-157.764	Level: $I(1)$ 1st Diff.: $I(0)$

Note 1) Critical value: ADF t-statistics 1% = -3.488, 5% = -2.886, 10% = -2.576; PP t-statistics: 1% = -20.017, 5% = -13.830, 10% = -11.087

[Table 30] Results for Johansen cointegration tests

Variables		H_0	Lag	λ_{trace}	Cointegration
Small tanker fleet development	China crude oil imports	$r = 0$	3	12.0158	O
		$r \leq 1$		3.5096	
	India crude oil imports	$r = 0$	3	20.7026	O
		$r \leq 1$		3.2639	
	U.S. oil product exports	$r = 0$	3	32.4265	O
		$r \leq 1$		3.2757	

Note 1) 5% critical value: r = 0, 15.41; r = 1, 3.76, 1% critical value: r = 0, 20.04; r = 1, 6.65

Note 2) The appropriate lag lengths were selected using Akaike's Information Criteria (AIC).

(2) Results for Granger causality tests

[Table 31] Results for Granger causality tests

Hypothesis	Long-run	Short-run	Strong
Small tanker fleet development ↛ China crude oil imports	-0.202*** (0.004)	-0.008 (0.249)	8.89*** (0.002)
China crude oil imports ↛ Small tanker fleet development	-0.144 (0.845)	0.413 (0.648)	0.21 (0.899)
Small tanker fleet development ↛ India crude oil imports	-0.361*** (0.000)	-0.005 (0.176)	18.27*** (0.000)
India crude oil imports ↛ Small tanker fleet development	-0.505 (0.775)	-1.391 (0.310)	2.35 (0.310)
Small tanker fleet development ↛ U.S. oil product exports	-0.439*** (0.000)	-0.002 (0.533)	29.42*** (0.000)
U.S. oil product exports ↛ Small tanker fleet development	-3.234 (0.140)	0.131 (0.955)	3.05 (0.218)

4.2.1.1.3 Price – Supply

(1) Results for cointegration tests

[Table 32] Results for ADF and PP unit root tests

	Variables	ADF		PP		Result
		Levels	First differences	Levels	First differences	
Supply	Crude Aframax fleet growth	-1.602	-11.494	-5.290	-160.257	Level: $I(1)$ 1st Diff.: $I(0)$
Price	1-year time charter rate (150,000 dwt)	-1.058	-9.240	-4.412	-105.430	Level: $I(1)$ 1st Diff.: $I(0)$
	1-year time charter rate (47-48,000 dwt)	-1.063	-8.593	-3.928	-92.435	Level: $I(1)$ 1st Diff.: $I(0)$
	1-year time charter rate (37,000 dwt)	-0.927	-8.930	-2.978	-93.975	Level: $I(1)$ 1st Diff.: $I(0)$
	3-year time charter rate (150,000 dwt)	-0.743	-7.846	-3.779	-89.506	Level: $I(1)$ 1st Diff.: $I(0)$

Note 1) Critical value: ADF t-statistics 1% = -3.488, 5% = -2.886, 10% = -2.576; PP t-statistics: 1% = -20.017, 5% = -13.830, 10% = -11.087

[Table 33] Results for Johansen cointegration tests

Variables		H_0	Lag	λ_{trace}	Cointegration
Crude Aframax fleet growth	1-year time charter rate (150,000 dwt)	$r = 0$	3	9.1091	O
		$r \leq 1$		0.6772	
	1-year time charter rate (47-48,000 dwt)	$r = 0$	2	8.3704	O
		$r \leq 1$		0.9150	
	1-year time charter rate (37,000 dwt)	$r = 0$	4	6.7053	O
		$r \leq 1$		0.5143	
	3-year time charter rate (150,000 dwt)	$r = 0$	4	13.3873	O
		$r \leq 1$		0.5819	

Note 1) 5% critical value: r = 0, 15.41; r = 1, 3.76, 1% critical value: r = 0, 20.04; r = 1, 6.65

Note 2) The appropriate lag lengths were selected using Akaike's Information Criteria (AIC).

(2) Results for Granger causality tests

[Table 34] Results for Granger causality tests

Hypothesis	Long-run	Short-run	Strong
Crude Aframax fleet growth ↛ 1-year time charter rate (150,000 dwt)	78.290 (0.172)	-356.840 (0.276)	2.99 (0.225)
1-year time charter rate (150,000 dwt) ↛ Crude Aframax fleet growth	-0.035*** (0.008)	0.000 (0.639)	7.41** (0.025)
Crude Aframax fleet growth ↛ 1-year time charter rate (47-48,000 dwt)	-0.029** (0.029)	55.630 (0.676)	4.98* (0.083)
1-year time charter rate (47-48,000 dwt) ↛ Crude Aframax fleet growth	0.000** (0.042)	0.000 (0.695)	4.19 (0.123)
Crude Aframax fleet growth ↛ 1-year time charter rate (37,000 dwt)	-0.013 (0.245)	-64.463 (0.571)	31.71 (0.441)
1-year time charter rate (37,000 dwt) ↛ Crude Aframax fleet growth	0.000** (0.022)	0.000 (0.160)	6.66** (0.036)
Crude Aframax fleet growth ↛ 3-year time charter rate (150,000 dwt)	42.332 (0.114)	-159.328 (0.309)	3.69 (0.158)
3-year time charter rate (150,000 dwt) ↛ Crude Aframax fleet growth	-0.043*** (0.001)	0.000 (0.951)	10.51*** (0.005)

4.2.1.2 The dry bulk market

The empirical results for the Johansen (1991) cointegration tests on demand and price variables for the tanker market, the optimal lags between price (6-month time charter rates for 75,000 dwt, 1-year time charter rates for 75,000 dwt and 3-year time charter rates for 75,000 dwt) and demand (China seaborne steam coal exports) were determined to be 4 months. When $r = 1$, trace statistics were analyzed to be less than 5% critical value (=3.76) thus the null hypothesis of having one or less cointegrating vector was rejected. Thus, these results explained that there more than one cointegrating vectors were in the presence between demand and price.

Also, the lag between supply (total bulk carrier development) and demand (China seaborne iron ore imports) was 4 months. When $r = 1$, trace statistic was analyzed to be less than 5% critical value and the null hypothesis of having one or less cointegrating vector was not rejected and it was analyzed that there only one cointegrating vector existed between the variables.

In addition, supply (bulk carrier fleet growth) and price (6-month time charter rate for 75,000 dwt, 1-year time charter rate for 75,000 dwt and 3-year time charter rate for 75,000 dwt) were cointegrated with the identical lag of 3 months. The null hypothesis of having one or less cointegrating vector was not rejected as trace statistics were less than 3.75.

The cointegrating equations between demand (china seaborne steam coal exports) and prices (6-month time charter rate for 75,000 dwt, 1-year time charter rate for 75,000 dwt and 3-year time charter rate for 75,000 dwt) are described in Eq. (4.2), Eq. (4.3) and Eq.

(4.4), respectively.

$$Demand_{t-1} = 6173.063 + 9.949 * Price_{t-1} + ECT_{t-1} \quad (4.2)$$

$$Demand_{t-1} = -598.707 + 0.108 * Price_{t-1} + ECT_{t-1} \quad (4.3)$$

$$Demand_{t-1} = -655.305 + 0.120 * Price_{t-1} + ECT_{t-1} \quad (4.4)$$

The long-run and the short-run Granger causality among demand, supply, and prices in the dry bulk market, and the causality coefficients are described in [Table 36], [Table 39] and [Table 42]. The results show that there long-term bidirectional causality exist between demand (China seaborne steam coal exports) and price (6-month time charter rates for 75,000 dwt) with the coefficients of 0.441 (demand to price) and -0.056 (price to demand). The results also indicate strong bidirectional Granger causality between demand (China seaborne iron ore imports) to supply (total bulk carrier development) with the coefficients of -0.256 (supply to demand) and 0.001 (demand to supply). These results indicate that changes in demand for bulk trade positively cause supply of bulk fleet in the long-run.

4.2.1.2.1 Demand – Price

(1) Results for cointegration tests

[Table 35] Results for ADF and PP unit root tests

	Variables	ADF		PP		Result
		Levels	First differences	Levels	First differences	
Demand	China seaborne steam coal exports	-1.189	-21.961	-8.346	-206.309	Level: $I(1)$ 1st Diff.: $I(0)$
Price	6-month time charter rates (75,000 dwt)	-1.506	-7.542	-9.186	-84.797	Level: $I(1)$ 1st Diff.: $I(0)$
	1-year time charter rates (75,000 dwt)	-1.390	-6.576	-8.622	-68.432	Level: $I(1)$ 1st Diff.: $I(0)$
	3-year time charter rates (75,000 dwt)	-1.539	-7.685	-8.933	-83.562	Level: $I(1)$ 1st Diff.: $I(0)$

Note 1) Critical value: ADF t-statistics 1% = -3.488, 5% = -2.886, 10% = -2.576; PP t-statistics: 1% = -20.017, 5% = -13.830, 10% = -11.087

[Table 36] Results for Johansen cointegration tests

Variables		H_0	Lag	λ_{trace}	Cointegration
China seaborne steam coal exports	6-month time charter rates (75,000 dwt)	$r = 0$	4	14.9415	O
		$r \leq 1$		4.8789	
	1-year time charter rates (75,000 dwt)	$r = 0$	4	14.2171	O
		$r \leq 1$		4.9695	
	3-year time charter rates (75,000 dwt)	$r = 0$	4	13.7501	O
		$r \leq 1$		4.6701	

Note 1) 5% critical value: r = 0, 15.41; r = 1, 3.76, 1% critical value: r = 0, 20.04; r = 1, 6.65

Note 2) The appropriate lag lengths were selected using Akaike's Information Criteria (AIC).

(2) Results for Granger causality tests

[Table 37] Results for Granger causality tests

Hypothesis	Long-run	Short-run	Strong
China seaborne steam coal exports ↛ 6-month time charter rates (75,000 dwt)	0.441** (0.015)	0.369 (0.394)	8.15** (0.017)
6-month time charter rates (75,000 dwt) ↛ China seaborne steam coal exports	-0.056* (0.085)	0.027* (0.056)	6.77** (0.034)
China seaborne steam coal exports ↛ 1-year time charter rates (75,000 dwt)	0.323** (0.019)	0.516 (0.115)	10.32*** (0.006)
1-year time charter rates (75,000 dwt) ↛ China seaborne steam coal exports	-0.052 (0.115)	0.045** (0.018)	8.05** (0.018)
China seaborne steam coal exports ↛ 3-year time charter rates (75,000 dwt)	-0.032** (0.027)	0.871*** (0.002)	18.31*** (0.000)
3-year time charter rates (75,000 dwt) ↛ China seaborne steam coal exports	0.007* (0.068)	0.025 (0.245)	4.63* (0.099)

4.2.1.2.2 Supply – Demand

(1) Results for cointegration tests

[Table 38] Results for ADF and PP unit root tests

	Variables	ADF		PP		Result
		Levels	First differences	Levels	First differences	
Supply	Total bulk carrier fleet development	-0.999	-7.589	-0.212	-101.257	Level: $I(1)$ 1st Diff.: $I(0)$
Demand	China seaborne iron ore imports	-2.420	-25.178	-4.544	-231.194	Level: $I(1)$ 1st Diff.: $I(0)$

Note 1) Critical value: ADF t-statistics 1% = -3.488, 5% = -2.886, 10% = -2.576; PP t-statistics: 1% = -20.017, 5% = -13.830, 10% = -11.087

[Table 39] Results for Johansen cointegration tests

Variables		H_0	Lag	λ_{trace}	Cointegration
Total bulk carrier fleet development	China seaborne iron ore imports	$r = 0$	4	10.7610	O
		$r \leq 1$		0.7774	

Note 1) 5% critical value: r = 0, 15.41; r = 1, 3.76, 1% critical value: r = 0, 20.04; r = 1, 6.65

Note 2) The appropriate lag lengths were selected using Akaike's Information Criteria (AIC).

(3) Results for Granger causality tests

[Table 40] Results for Granger causality tests

Hypothesis	Long-run	Short-run	Strong
Total bulk carrier fleet development ↛ China seaborne iron ore imports	-0.256*** (0.003)	38.186* (0.099)	10.59*** (0.005)
China seaborne iron ore imports ↛ Total bulk carrier fleet development	0.001* (0.064)	0.000 (0.597)	8.92** (0.012)

4.2.1.2.3 Price – Supply

(1) Results of cointegration tests

[Table 41] Results for ADF and PP unit root tests

	Variables	ADF Levels	ADF First differences	PP Levels	PP First differences	Result
Supply	Bulk carrier fleet growth	-0.354	-6.739	-1.871	-75.252	Level: $I(1)$ 1st Diff.: $I(0)$
Price	6-month time charter rates (75,000 dwt)	-1.506	-7.542	-9.186	-84.797	Level: $I(1)$ 1st Diff.: $I(0)$
	1-year time charter rates (75,000 dwt)	-1.390	-6.576	-8.622	-68.432	Level: $I(1)$ 1st Diff.: $I(0)$
	3-year time charter rates (75,000 dwt)	-1.539	-7.685	-8.933	-83.562	Level: $I(1)$ 1st Diff.: $I(0)$

Note 1) Critical value: ADF t-statistics 1% = -3.488, 5% = -2.886, 10% = -2.576; PP t-statistics: 1% = -20.017, 5% = -13.830, 10% = -11.087

[Table 42] Results for Johansen cointegration tests

Variables		H_0	Lag	λ_{trace}	Cointegration
Bulk carrier fleet growth	6-month time charter rates (75,000 dwt)	$r = 0$	3	9.0285	O
		$r \leq 1$		1.7427	
	1-year time charter rates (75,000 dwt)	$r = 0$	3	8.3214	O
		$r \leq 1$		1.8065	
	3-year time charter rates (75,000 dwt)	$r = 0$	3	8.6947	O
		$r \leq 1$		1.9314	

Note 1) 5% critical value: r = 0, 15.41; r = 1, 3.76, 1% critical value: r = 0, 20.04; r = 1, 6.65

Note 2) The appropriate lag lengths were selected using Akaike's Information Criteria (AIC).

(3) Results of Granger causality tests

[Table 43] Results for Granger causality tests

Hypothesis	Long-run	Short-run	Strong
Bulk carrier fleet growth ↛ 6-month time charter rates (75,000 dwt)	-0.040** (0.016)	302.614 (0.750)	5.82* (0.054)
6-month time charter rates (75,000 dwt) ↛ Bulk carrier fleet growth	0.000 (0.134)	0.000 (0.610)	2.57 (0.277)
Bulk carrier fleet growth ↛ 1-year time charter rates (75,000 dwt)	-0.032** (0.018)	656.674 (0.361)	6.04** (0.049)
1-year time charter rates (75,000 dwt) ↛ Bulk carrier fleet growth	0.000 (0.210)	0.000 (0.768)	1.65 (0.439)
Bulk carrier fleet growth ↛ 3-year time charter rates (75,000 dwt)	-0.044** (0.012)	349.884 (0.593)	6.39** (0.041)
3-year time charter rates (75,000 dwt) ↛ Bulk carrier fleet growth	0.000 (0.315)	0.000 (0.696)	1.18 (0.554)

4.2.1.3 The container market

[Table 44] and [Table 46] respectively describes the results for unit root tests of demand (Asia-Europe container growth), price (Shanghai-Durban rate), demand (China seaborne containerized imports) and supply (total container fleet development). However, demand (Asia-Europe container trade grade growth and China seaborne containerized imports), and supply (total container fleet development) were determined to be $I(0)$ series. Thus, this study first order differenced price (SCFI Shanghai-Durban rates) time series to estimate VAR models. The null hypotheses of having no existence of short-run causality running from price to demand and demand to price could not be rejected. The null hypotheses of the having no causality between supply and demand could not be rejected as well.

[Table 48] shows that supply (total container charter owner fleet development) and price (SCFI Shanghai-Mediterranean rates and SCFI Shanghai-West U.S. rates) were cointegrated with the lag of 4 months. [Table 49] explains that the null hypothesis of having no causality running from supply (total container charter owner fleet development) to price (SCFI Shanghai-West U.S. rate) was rejected at 1% significance level. This can be interpreted that there a strong unidirectional Granger causality running from supply to price in the long-run with the coefficient of -0.317 exists in the container-ship market. Cointegrating equation is in Eq. (4.5) and the [Table 49] describes that there is only one cointegrating vector between supply and price.

$$Supply_{t-1} = 7161.522 - 4.895 * Price_{t-1} + ECT_{t-1} \qquad (4.5)$$

4.2.1.3.1 Demand – Price

(1) Results for unit root tests

[Table 44] Results for ADF and PP unit root tests

	Variables	ADF		PP		Result
		Levels	First differences	Levels	First differences	
Price	SCFI Shanghai-Durban rate	-1.886	-6.939	-6.892	-64.908	Level: $I(1)$ 1st Diff.: $I(0)$
Demand	Asia-Europe container trade growth	-7.790	-19.819	-90.970	-145.923	Level: $I(0)$ 1st Diff.: $I(0)$

Note 1) Critical value: ADF t-statistics 1% = -3.488, 5% = -2.886, 10% = -2.576; PP t-statistics: 1% = -20.017, 5% = -13.830, 10% = -11.087

(2) Results for VAR estimations

[Table 45] Results for Granger causality tests

Hypothesis	Short-run
SCFI Shanghai-Durban rate $\nrightarrow$ Asia-Europe container trade growth	0.115 (0.944)
Asia-Europe container trade growth $\nrightarrow$ SCFI Shanghai-Durban rate	0.672 (0.714)

4.2.1.3.2 Supply – Demand

(1) Results for unit root tests

[Table 46] Results for ADF and PP unit root tests

	Variables	ADF		PP		Result
		Levels	First differences	Levels	First differences	
Supply	Total container fleet development	-4.586	-4.734	-4.483	-35.596	Level: $I(0)$ 1st Diff.: $I(0)$
Demand	China seaborne containerized imports	-8.848	-16.210	-95.622	-115.457	Level: $I(0)$ 1st Diff.: $I(0)$

Note 1) Critical value: ADF t-statistics 1% = -3.488, 5% = -2.886, 10% = -2.576; PP t-statistics: 1% = -20.017, 5% = -13.830, 10% = -11.087

(2) Results for VAR estimations

[Table 47] Results for Granger causality tests

Hypothesis	Short-run
Total container fleet development ↛ China seaborne containerized imports	5.283 (0.152)
China seaborne containerized imports ↛ Total container carrier fleet development	4.272 (0.234)

4.2.1.3.3 Price – Supply

(1) Results for cointegration tests

[Table 48] Results for ADF and PP unit root tests

	Variables	ADF		PP		Result
		Levels	First differences	Levels	First differences	
Supply	Total container charter owner fleet development	2.730	-5.125	1.861	-41.591	Level: *I*(1) 1st Diff.: *I*(0)
Price	SCFI Shanghai-Mediterranean rate	-2.314	-7.967	-11.557	-64.787	Level: *I*(1) 1st Diff.: *I*(0)
Price	SCFI Shanghai-West U.S. rate	-2.128	-9.166	-10.946	-84.293	Level: *I*(1) 1st Diff.: *I*(0)

Note 1) Critical value: ADF t-statistics 1% = -3.488, 5% = -2.886, 10% = -2.576; PP t-statistics: 1% = -20.017, 5% = -13.830, 10% = -11.087

[Table 49] Results for Johansen cointegration tests

Variables		H_0	Lag	λ_{trace}	Cointegration
Total container charter owner fleet development	SCFI Shanghai-Mediterranean rate	$r = 0$	4	6.7612	O
		$r \leq 1$		0.1551	
	SCFI Shanghai-West U.S. rate	$r = 0$	4	8.0283	O
		$r \leq 1$		0.4122	

Note 1) 5% critical value: r = 0, 15.41; r = 1, 3.76, 1% critical value: r = 0, 20.04; r = 1, 6.65

Note 2) The appropriate lag lengths were selected using Akaike's Information Criteria (AIC).

(2) Results for Granger causality tests

[Table 50] Results for Granger causality tests

Hypothesis	Long-run	Short-run	Strong
Total container charter owner fleet development ↛ SCFI Shanghai-Mediterranean rate	0.280*** (0.006)	0.146 (0.955)	7.77** (0.021)
SCFI Shanghai-Mediterranean rate ↛ Total container charter owner fleet development	-0.001 (0.809)	-0.001 (0.955)	0.24 (0.886)
Total container charter owner fleet development ↛ SCFI Shanghai-West U.S. rate	-0.317*** (0.003)	-0.029* (0.099)	11.36*** (0.003)
SCFI Shanghai-West U.S. rate ↛ Total container charter owner fleet development	-0.003 (0.296)	-0.003 (0.282)	2.80* (0.076)

4.2.2 Hypothesis II: Lead-lag relationship exists between the dry bulk and the container shipping markets.

4.2.2.1 Dry bulk – Container markets

[Table 50] describes that demand for bulk (Ukraine iron ore exports) and price of container shipping (SCFI Shanghai-Europe rates) are cointegrated with the lag of 2 months. [Table 51] illustrates that the null hypothesis of having no causality running from demand for bulk to container shipping freight rates was rejected thus there is a strong Granger causality running from demand for bulk to price of container shipping. The causality coefficient was -0.198.

[Table 55] shows that demand for dry bulk trade (China seaborne iron ore imports) and supply of container fleet are cointegrated with the lag of 4 months. According to [Table 56], the null hypothesis of having no causality running from China seaborne iron ore imports to total container ships fleet development was rejected at 5% significance level. The causality coefficient was 0.006 and the cointegrating equation is Eq. (4.6). Thus, it was found that changes in demand for dry bulk precedes changes in supply of container-ship fleet 4 months ahead.

Regarding the relationship of supply and price in the dry bulk and the container-ship markets, [Table 58] describes that supply of bulk fleet and container-ship freight rates were cointegrated with the lag of 3 months. According to [Table 59], there was a bidirectional Granger causality between supply of bulk ships and price of container transport, however, it was determined that the causality was not strong. The causality coefficients were 0.032 (supply to price) and 0.004 (price to supply) which denote that the causality from supply to price is larger than the causality from price to supply. The cointegrating equation is in Eq. (4.7).

$$Demand_{t-1} = 8701.074 - 477.344 * Supply_{t-1} + ECT_{t-1} \qquad (4.6)$$

$$Supply_{t-1} = 2349.688 - 3.044 * Price_{t-1} + ECT_{t-1} \qquad (4.7)$$

4.2.2.1.1 Demand – Price

(1) Results for cointegration tests

[Table 51] Results for ADF and PP unit root tests

	Variables	ADF		PP		Result
		Levels	First differences	Levels	First differences	
Price	SCFI Shanghai-Europe rate	-2.344	-8.363	-10.849	-67.652	Level: $I(1)$ 1st Diff.: $I(0)$
Demand	Ukraine iron ore exports	-2.329	-13.000	-7.888	-111.222	Level: $I(1)$ 1st Diff.: $I(0)$

Note 1) Critical value: ADF t-statistics 1% = -3.488, 5% = -2.886, 10% = -2.576; PP t-statistics: 1% = -20.017, 5% = -13.830, 10% = -11.087

[Table 52] Results for Johansen cointegration tests

Variables		H_0	Lag	λ_{trace}	Cointegration
SCFI Shanghai-Europe rate	Ukraine iron ore exports	$r = 0$	2	19.0891	O
		$r \leq 1$		2.8047	

Note 1) 5% critical value: r = 0, 15.41; r = 1, 3.76, 1% critical value: r = 0, 20.04; r = 1, 6.65

Note 2) The appropriate lag lengths were selected using Akaike's Information Criteria (AIC).

(3) Results for Granger causality tests

[Table 53] Results for Granger causality tests

Hypothesis	Long-run	Short-run	Strong
SCFI Shanghai-Europe rate ↛ Ukraine iron ore exports	-0.160 (0.100)	-0.123 (0.471)	4.46 (0.107)
Ukraine iron ore exports ↛ SCFI Shanghai-Europe rate	-0.198*** (0.001)	0.046 (0.422)	12.15*** (0.002)

4.2.2.1.2 Supply – Demand

(2) Results for cointegration tests

[Table 54] Results for ADF and PP unit root tests

	Variables	ADF		PP		Result
		Levels	First differences	Levels	First differences	
Demand	China seaborne iron ore imports	-2.255	-17.894	-4.973	-140.363	Level: $I(1)$ 1st Diff.: $I(0)$
Supply	Total container ships fleet development	-1.499	-2.138	-1.478	-157.764	Level: $I(1)$ 1st Diff.: $I(0)$

Note 1) Critical value: ADF t-statistics 1% = -3.488, 5% = -2.886, 10% = -2.576; PP t-statistics: 1% = -20.017, 5% = -13.830, 10% = -11.087

[Table 55] Results for Johansen cointegration tests

Variables		H_0	Lag	λ_{trace}	Cointegration
Total container ships fleet development	China seaborne iron ore imports	$r = 0$	4	14.4823	O
		$r \leq 1$		3.5026	

Note 1) 5% critical value: r = 0, 15.41; r = 1, 3.76, 1% critical value: r = 0, 20.04; r = 1, 6.65

Note 2) The appropriate lag lengths were selected using Akaike's Information Criteria (AIC).

(3) Results for Granger causality tests

[Table 56] Results for Granger causality tests

Hypothesis	Long-run	Short-run	Strong
Total container ships fleet development ↛ China seaborne iron ore imports	0.000 (0.102)	-0.008 (0.192)	6.29** (0.043)
China seaborne iron ore imports ↛ Total container ships fleet development	0.006** (0.010)	-1.540 (0.400)	6.65** (0.036)

4.2.2.1.3 Price – Supply

(1) Results for cointegration tests

[Table 57] Results for ADF and PP unit root tests

	Variables	ADF		PP		Result
		Levels	First differences	Levels	First differences	
Price	SCFI Shanghai-Europe rate	-2.344	-8.363	-10.849	-67.652	Level: $I(1)$ 1st Diff.: $I(0)$
Supply	Total bulk carrier fleet development	9.953	-4.867	1.658	-34.186	Level: $I(1)$ 1st Diff.: $I(0)$

Note 1) Critical value: ADF t-statistics 1% = -3.488, 5% = -2.886, 10% = -2.576; PP t-statistics: 1% = -20.017, 5% = -13.830, 10% = -11.087

[Table 58] Results for Johansen cointegration tests

Variables		H_0	Lag	λ_{trace}	Cointegration
Total bulk carrier fleet development	SCFI Shanghai-Europe rate	$r = 0$	3	20.5471	O
		$r \leq 1$		3.9047	

Note 1) 5% critical value: r = 0, 15.41; r = 1, 3.76, 1% critical value: r = 0, 20.04; r = 1, 6.65

Note 2) The appropriate lag lengths were selected using Akaike's Information Criteria (AIC).

(2) Results for Granger causality tests

[Table 59] Results for Granger causality tests

Hypothesis	Long-run	Short-run	Strong
Total bulk carrier fleet development	0.032**	-0.008	1.43
↛ SCFI Shanghai-Europe rate	(0.039)	(0.386)	(0.232)
SCFI Shanghai-Europe rate	0.004***	-1.410	4.57
↛ Total bulk carrier fleet development	(0.004)	(0.232)	(0.102)

4.2.3 Hypothesis III: Bilateral short-run equilibrium exists between the dry bulk and the tanker shipping markets.

4.2.3.1 Dry bulk – tanker markets

[Table 61] illustrates that demand for dry bulk trade (Russian iron ore exports) and price of tanker shipping (1-year time charter rate for 150,000 dwt) are cointegrated with the lag of 4 months. [Table 62] shows that the null hypothesis of having no Granger causality from price to demand was rejected at 1% significance level. This indicates that there is a strong Granger causality running from price of tanker transport to demand for dry bulk trade with the causality coefficient of 0.005.

[Table 64] shows that demand for dry bulk (China seaborne steam coal exports) and supply of tankers fleet (small tankers fleet development), and demand for oil trade (U.S seaborne crude oil imports) and supply of bulk ships (total bulk carrier fleet development) are cointegrated with the lag of 3 months and 3months, respectively. The results of Granger causality tests described in [Table 65] indicate that there is a long-run strong Granger causality running from supply of bulk fleet (total bulk carrier fleet development) to demand for oil trade (China steam coal exports) with the coefficient of -0.415 and a short-run Granger causality in the inverse direction with the coefficient of -16.824. Eq. (4.8) and Eq. (4.9) are the cointegrating equations with ECTs for the causality from supply of tanker fleet (small tankers fleet development) to demand for dry bulk (China seaborne steam coal exports) and the causality from demand for bulk (total bulk carrier fleet development) to demand for oil trade (U.S. seaborne crude oil imports), respectively.

Furthermore, price of tanker freight shipping (1-year time charter rate for 150,000 dwt) and supply of bulk ship fleet (total bulk carrier fleet development) were cointegrated with the lag of 3 months. There was a strong long-run bidirectional Granger causality between the variables in which total bulk carrier fleet development Granger causes 1-year time charter rate for 150,000 dwt with the coefficient of -0.072 and the inverse causality with the coefficient of -0.001.

$$Supply_{t-1} = 14666.77 - 5.049 * Demand_{t-1} + ECT_{t-1} \qquad (4.8)$$

$$Demand_{t-1} = 14048.84 - 1215.964 * Supply_{t-1} + ECT_{t-1} \qquad (4.9)$$

4.2.3.1.1 Demand – Price

(1) Results for cointegration tests

[Table 60] Results for ADF and PP unit root tests

	Variables	ADF		PP		Result
		Levels	First differences	Levels	First differences	
Price	1-year time charter rate (150,000 dwt)	-1.058	-9.240	-4.412	-105.430	Level: $I(1)$ 1st Diff.: $I(0)$
Demand	Russia iron ore exports	-2.108	-18.874	-10.976	-194.051	Level: $I(1)$ 1st Diff.: $I(0)$

Note 1) Critical value: ADF t-statistics 1% = -3.488, 5% = -2.886, 10% = -2.576; PP t-statistics: 1% = -20.017, 5% = -13.830, 10% = -11.087

[Table 61] Results for Johansen cointegration tests

Variables		H_0	Lag	λ_{trace}	Cointegration
1-year time charter rates (150,000 dwt)	Russia iron ore exports	$r = 0$	4	8.3188	O
		$r \leq 1$		1.8576	

Note 1) 5% critical value: r = 0, 15.41; r = 1, 3.76, 1% critical value: r = 0, 20.04; r = 1, 6.65

Note 2) The appropriate lag lengths were selected using Akaike's Information Criteria (AIC).

(2) Results for Granger causality tests

[Table 62] Results for Granger causality tests

Hypothesis	Long-run	Short-run	Strong
1-year time charter rates (150,000 dwt)	0.005***	0.009	9.03**
↛ Russia iron ore exports	(0.003)	(0.755)	(0.011)
Russia iron ore exports	-0.002	-0.143	0.54
↛ 1-year time charter rates (150,000 dwt)	(0.748)	(0.468)	(0.762)

4.2.3.1.2 Supply – Demand

(1) Results for cointegration tests

[Table 63] Results for ADF and PP unit root tests

	Variables	ADF		PP		Result
		Levels	First differences	Levels	First differences	
Demand	China seaborne steam coal exports	-3.189	-21.961	-8.346	-206.309	Level: $I(1)$ 1st Diff.: $I(0)$
	U.S. seaborne crude oil imports	-1.546	-21.136	-2.138	-228.348	Level: $I(1)$ 1st Diff.: $I(0)$
Supply	Small tankers fleet development	-2.433	-9.739	-0.501	-146.378	Level: $I(1)$ 1st Diff.: $I(0)$
	Total bulk carrier fleet development	-0.999	-7.589	-0.212	-101.257	Level: $I(1)$ 1st Diff.: $I(0)$

Note 1) Critical value: ADF t-statistics 1% = -3.488, 5% = -2.886, 10% = -2.576; PP t-statistics: 1% = -20.017, 5% = -13.830, 10% = -11.087

[Table 64] Results for Johansen cointegration tests

Variables		H_0	Lag	λ_{trace}	Cointegration
China seaborne steam coal exports	Small tankers fleet development	$r = 0$	3	27.4496	O
		$r \leq 1$		3.9802	
Total bulk carrier fleet development	U.S. seaborne crude oil imports	$r = 0$	3	21.1653	O
		$r \leq 1$		0.6114	

Note 1) 5% critical value: r = 0, 15.41; r = 1, 3.76, 1% critical value: r = 0, 20.04; r = 1, 6.65

Note 2) The appropriate lag lengths were selected using Akaike's Information Criteria (AIC).

(2) Results for Granger causality tests

[Table 65] Results for Granger causality tests

Hypothesis	Long-run	Short-run	Strong
China seaborne steam coal exports ↛ Small tankers fleet development	-0.001 (0.312)	-16.824* (0.094)	22.80*** (0.000)
Small tankers fleet development ↛ China seaborne steam coal exports	-0.415*** (0.000)	-0.001 (0.384)	4.62* (0.099)
Total bulk carrier fleet development ↛ U.S. seaborne crude oil imports	-0.0002*** (0.000)	-0.002 (0.221)	24.49*** (0.000)
U.S. seaborne crude oil imports ↛ Total bulk carrier fleet development	0.005 (0.220)	-5.773 (0.268)	1.77 (0.413)

4.2.3.1.3 Price – Supply

(1) Results for cointegration tests

[Table 66] Results for ADF and PP unit root tests

	Variables	ADF		PP		Result
		Levels	First differences	Levels	First differences	
Price	1-year time charter rate (150,000 dwt)	-1.058	-9.240	-4.412	-105.430	Level: $I(1)$ 1st Diff.: $I(0)$
Supply	Total bulk carrier fleet development	-0.999	-7.589	-0.212	-101.257	Level: $I(1)$ 1st Diff.: $I(0)$

Note 1) Critical value: ADF t-statistics 1% = -3.488, 5% = -2.886, 10% = -2.576; PP t-statistics: 1% = -20.017, 5% = -13.830, 10% = -11.087

[Table 67] Results for Johansen cointegration tests

Variables		H_0	Lag	λ_{trace}	Cointegration
Total bulk carrier fleet development	1-year time charter rate (150,000 dwt)	$r = 0$	3	18.0306	O
		$r \leq 1$		0.1698	

Note 1) 5% critical value: r = 0, 15.41; r = 1, 3.76, 1% critical value: r = 0, 20.04; r = 1, 6.65

Note 2) The appropriate lag lengths were selected using Akaike's Information Criteria (AIC).

(2) Results for Granger causality tests

[Table 68] Results for Granger causality tests

Hypothesis	Long-run	Short-run	Strong
Total bulk carrier fleet development	-0.072***	-8.683	7.42**
↛ 1-year time charter rate (150,000 dwt)	(0.007)	(0.279)	(0.025)
1-year time charter rate (150,000 dwt)	-0.001***	0.001	9.91***
↛ Total bulk carrier fleet development	(0.002)	(0.461)	(0.007)

4.2.4 Hypothesis IV: The tanker and the container shipping markets are interrelated

4.2.4.1 Tanker – Container markets

[Table 69] indicates that the time series of demand for container trade (China seaborne containerized imports) is $I(0)$ so that this study first differenced the time series of price of oil transport (1-year time charter rate for 150,000 dwt) and demand for the container trade (China seaborne containerized imports) to estimate a VAR model. However, as illustrated in [Table 70], the null hypotheses of having no Granger causality running from 1-year time charter rates to China seaborne containerized imports and having no Granger causality in the inverse direction could not be rejected.

[Table 72] denotes that demand for oil shipping (U.S. seaborne crude oil imports) and supply of container-ship fleet (total container charter owner fleet development) were cointegrated under more than one cointegrating vector with the lag of 3 months. [Table 73] shows that there is a strong Granger causality running from U.S. seaborne crude oil imports to total container charter owner development with the coefficient of -2.787. This indicates that changes in demand for tanker precede changes in supply of container fleet 3 months ahead. The cointegrating equation of demand for oil shipping and supply of container fleet with an ECT is Eq. (4.10).

Lastly, price of tanker shipping (1-year time charter rate for 150,000 dwt) and supply of container fleet (total container charter owner fleet development) had only one cointegrating vector with the lag of 2 months. [Table 74] illustrates that price of oil shipping and supply of container fleet are in the long-run bidirectional Granger causality with the coefficients of 0.294 (price to supply) and -0.039 (supply to price). On the other hand, supply of tanker fleet (small tankers fleet development) and price of container freight transport (SCFI Shanghai-Mediterranean rate) were under one cointegrating vector with the lag of 3 months. [Table 74] describes that there is a Granger causality running from supply of tanker fleet to price of container freight transport.

$$Demand_{t-1} = 83.371 - 0.015 * Supply_{t-1} + ECT_{t-1} \quad (4.10)$$

4.2.4.1.1 Demand – Price

(1) Results for unit root tests

[Table 69] Results for ADF and PP unit root tests

	Variables	ADF		PP		Result
		Levels	First differences	Levels	First differences	
Price	1-year time charter rate (150,000 dwt)	-0.773	-7.078	-3.184	-62.672	Level: $I(1)$ 1st Diff.: $I(0)$
Demand	China seaborne containerized imports	-8.848	-16.210	-95.622	-115.457	Level: $I(0)$ 1st Diff.: $I(0)$

Note 1) Critical value: ADF t-statistics 1% = -3.488, 5% = -2.886, 10% = -2.576; PP t-statistics: 1% = -20.017, 5% = -13.830, 10% = -11.087

(2) Results for Granger causality tests

[Table 70] Results for Granger causality tests

Hypothesis	Short-run
1-year time charter rates (150,000 dwt) ↛ China seaborne containerized imports	4.095 (0.251)
China seaborne containerized imports ↛ 1-year time charter rates (150,000 dwt)	2.948 (0.400)

4.2.4.1.2 Supply – Demand

(1) Results for cointegration tests

[Table 71] Results for ADF and PP unit root tests

	Variables	ADF		PP		Result
		Levels	First differences	Levels	First differences	
Demand	U.S. seaborne crude oil imports	-2.847	-16.570	-10.617	-135.889	Level: *I*(1) 1st Diff.: *I*(0)
Supply	Total container charter owner fleet development	2.730	-5.125	1.861	-41.591	Level: *I*(1) 1st Diff.: *I*(0)

Note 1) Critical value: ADF t-statistics 1% = -3.488, 5% = -2.886, 10% = -2.576; PP t-statistics: 1% = -20.017, 5% = -13.830, 10% = -11.087

[Table 72] Results for Johansen cointegration tests

Variables		H_0	Lag	λ_{trace}	Cointegration
U.S. seaborne crude oil imports	Total container charter owner fleet development	$r = 0$	3	17.1307	O
		$r \leq 1$		3.5721	

Note 1) 5% critical value: r = 0, 15.41; r = 1, 3.76, 1% critical value: r = 0, 20.04; r = 1, 6.65

Note 2) The appropriate lag lengths were selected using Akaike's Information Criteria (AIC).

(2) Results for Granger causality tests

[Table 73] Results for Granger causality tests

Hypothesis	Long-run	Short-run	Strong
U.S. seaborne crude oil imports ↛ Total container charter owner fleet development	-2.787*** (0.001)	2.640 (0.143)	11.67*** (0.003)
Total container charter owner fleet development ↛ U.S. seaborne crude oil imports	-0.029 (0.557)	-0.011* (0.089)	2.93 (0.231)

4.2.4.1.3 Price – Supply

(1) Results for cointegration tests

[Table 74] Results for ADF and PP unit root tests

	Variables	ADF		PP		Result
		Levels	First differences	Levels	First differences	
Demand	1-year time charter rate (150,000 dwt)	-0.773	-7.078	-3.184	-62.672	Level: $I(1)$ 1^{st} Diff.: $I(0)$
Demand	SCFI Shanghai-Mediterranean rate	-2.314	-7.967	-11.557	-64.787	Level: $I(1)$ 1^{st} Diff.: $I(0)$
Supply	Total container charter owner fleet development	2.730	-5.125	1.861	-41.591	Level: $I(1)$ 1^{st} Diff.: $I(0)$
Supply	Small tankers fleet development	-2.433	-9.739	-0.501	-146.378	Level: $I(1)$ 1^{st} Diff.: $I(0)$

Note 1) Critical value: ADF t-statistics 1% = -3.488, 5% = -2.886, 10% = -2.576; PP t-statistics: 1% = -20.017, 5% = -13.830, 10% = -11.087

[Table 75] Results for Johansen cointegration tests

Variables		H_0	Lag	λ_{trace}	Cointegration
1-year time charter rate (150,000 dwt)	Total container charter owner fleet development	$r = 0$	2	19.0631	O
		$r \leq 1$		2.6500	
Small tankers fleet development	SCFI Shanghai-Mediterranean rate	$r = 0$	3	13.9076	O
		$r \leq 1$		0.0671	

Note 1) 5% critical value: r = 0, 15.41; r = 1, 3.76, 1% critical value: r = 0, 20.04; r = 1, 6.65

Note 2) The appropriate lag lengths were selected using Akaike's Information Criteria (AIC).

(3) Results for Granger causality tests

[Table 76] Results for Granger causality tests

Hypothesis	Long-run	Short-run	Strong
1-year time charter rate (150,000 dwt) ↛ Total container charter owner fleet development	0.294*** (0.002)	-31.315 (0.291)	10.24*** (0.006)
Total container charter owner fleet development ↛ 1-year time charter rate (150,000 dwt)	-0.039** (0.018)	0.000 (0.789)	5.71* (0.058)
Small tankers fleet development ↛ SCFI Shanghai-Mediterranean rate	-0.228*** (0.000)	-1.278 (0.671)	0.98 (0.613)
SCFI Shanghai-Mediterranean rate ↛ Small tankers fleet development	0.002 (0.350)	0.0003 (0.917)	0.01 (0.917)

Chapter 5. Conclusion

This study analyzed the causal dynamics within a single seaborne shipping market and between the major seaborne shipping markets. The major seaborne shipping markets include tanker market, dry bulk market and container market. This study considered demand, supply, and prices (freight rates) which mutually interact under the supply and demand theory in the maritime shipping industry. The supply and demand model in the shipping markets illustrates that shipowners adjust supply of ships to changes in demand for commodity trade. Supply of fleet tends to increase as demand for trade increases. As well, charters adjust freight rates to changes in as the volume of trade. Freight rates tend to rise as the volume of commodity trade increases. This study used monthly time series data of 28 variables during 2004:05-2018:03 (tanker and dry bulk markets) and 2009:12-2018:03 (container markets) to investigate the Granger causality. The Granger causality test begins with the step of testing cointegration relations of time series and ends with estimating VEC models. The conclusion consists of two parts: the first part summarizing the empirical results for a single market causality and the second part describing the causal evidence between multiple markets.

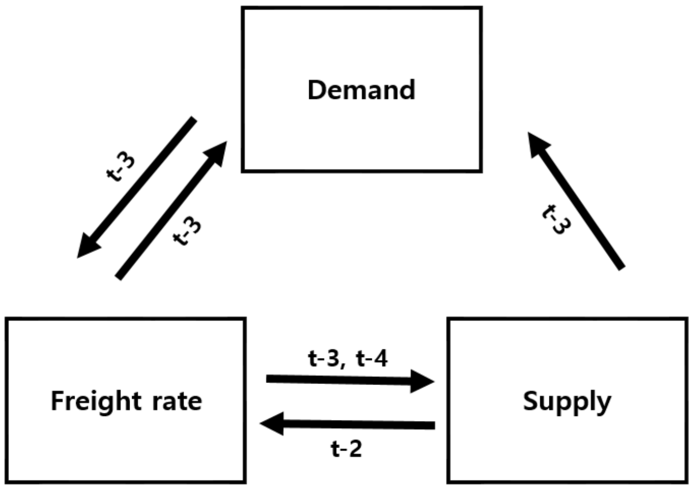
5.1 Summary of results for causality within a single market

The research methodology used in this study is the Granger causality test through the Johansen cointegration test. The initial step of the empirical analysis in this research is to test the existence of unit roots in the time series data. The presence of unit roots indicates that the time series is non-stationary. All the time series were determined to have unit roots except for the data of Asia-Europe container trade growth (supply variable for the container market), total container fleet development (supply variable for the container market) and seaborne containerized imports for China (demand variable for the container market). The other 25 time-series were determined to be non-stationary. However, the series became stationary after first order differencing.

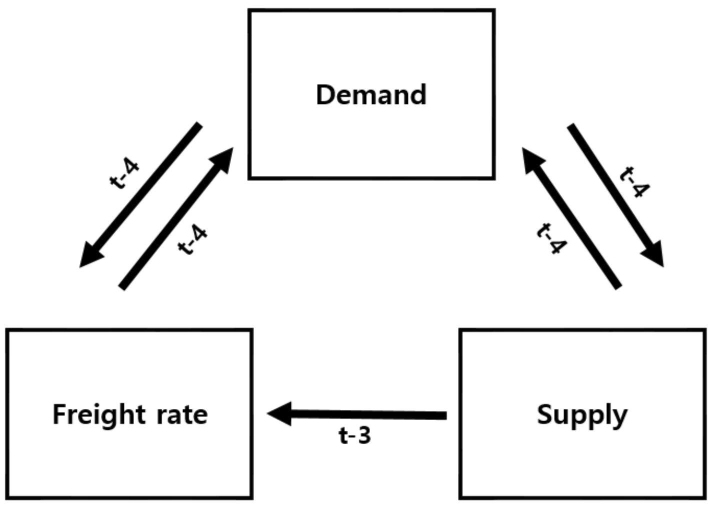
Using the other 25 time-series which were analyzed to be non-stationary, this study conducted the Johansen cointegration tests to investigate the long-run equilibrium relationship between demand, supply, and prices in a single market (Hypothesis I). For the tanker market, demand (U.S. oil product exports) and price (1-year time charter rate for medium range), supply (small tanker development) and demand (China crude oil imports, India crude oil imports, U.S. oil product exports) and supply (Crude Aframax fleet growth) and price (1-year time charter rate for 150,000 dwt, 1-year time charter rate for 47-48,000 dwt, 1-year time charter rate for 37,000 dwt, 3-year time charter rate for 150,000 dwt) were cointegrated. For the dry bulk market, demand (China seaborne steam coal exports) and price (6-month time charter rates for 75,000 dwt, 1-year time charter rates for 75,000 dwt, 3-year time charter rates for 75,000 dwt), supply (total bulk carrier development) and demand (China seaborne iron ore imports) and supply (bulk carrier fleet growth) and price (6-month time charter rates for 75,000 dwt, 1-year time charter rates for 75,000 dwt, 3-year time charter rates for 75,000 dwt) were cointegrated whilst supply (total container charter owner fleet development) and price (SCFI Shanghai-Mediterranean rates, SCFI Shanghai-West U.S. rates) were cointegrated in the container market.

After cointegration tests, this study analyzed Granger causality of the cointegrated time series through VEC model estimations. For the tanker market, this study found strong Granger causality running from price (1-year time charter rate for medium range) to demand (U.S. oil product exports) and from supply (Crude Aframax fleet growth) to price (1-year time charter rate for 47-48,000 dwt). Furthermore, this study detected strong Granger causality flowing from demand (china seaborne steam coal exports) to price (6-month time charter rates for 75,000 dwt), demand (China seaborne iron ore imports) to supply (total bulk carrier fleet development), supply (bulk carrier fleet growth) to price (6-month time charter rates for 75,000 dwt) in the dry bulk market. This research also found a strong Granger causality running from supply (total container charter owner fleet development) to price (SCFI Shanghai-Mediterranean rate) in the container market. These strong Granger causalities were in the long-run equilibrium. These empirical results prove that the long-run equilibrium relationship exists among demand, supply, and prices in each of the three major shipping markets: tanker, dry bulk and container markets. Therefore, it can be confirmed that the internal mechanism which fluctuate demand, supply, and freight rate in the shipping markets is the supply and demand model.

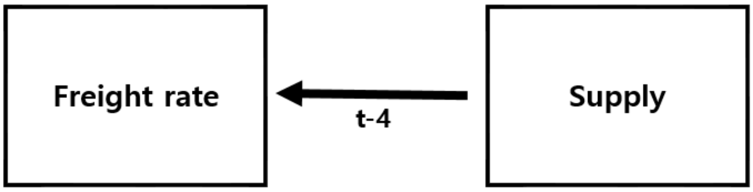
<Fig. 18> Causal relationships within tanker market



<Fig. 19> Causal relationships within dry bulk market



<Fig. 20> Causal relationships within container-ship market

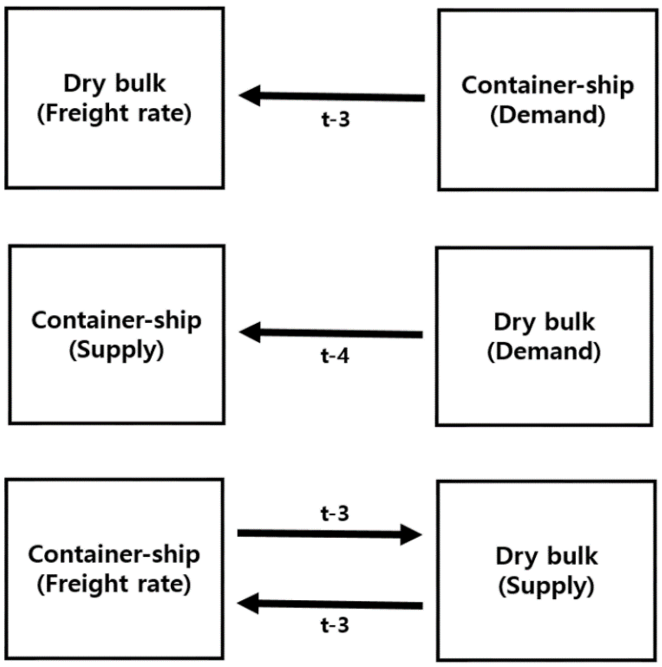


5.2 Summary of results for causality among multiple markets

This study also tested whether the dry bulk market and the container shipping markets are in the lead-lag relationship (Hypothesis II), the dry bulk and the tanker markets are in the bilateral short-run equilibrium relationship and the tanker (Hypothesis III), and the container markets are interrelated (Hypothesis IV) through Granger causality tests with VEC model estimations.

First of all, this study detected strong Granger causality running from demand for dry bulk trade (Ukraine iron ore exports) to price of container shipping (SCFI Shanghai-Europe rates) with the lag of 2, from demand for dry bulk trade (china seaborne iron ore imports) to supply (total container ships fleet development) with the lag of 4, from supply of bulk fleet (total bulk carrier fleet development) to price (SCFI Shanghai-Europe rates) with the lag of 3. These results confirm that the dry bulk shipping market precedes the container shipping markets in terms of changes in demand, supply, and freight rates. It can be analyzed that this is due to the characteristics of the dry bulk and the container markets that dry bulk ships generally transport raw materials while container ships mainly transport semi-finished or finished products.

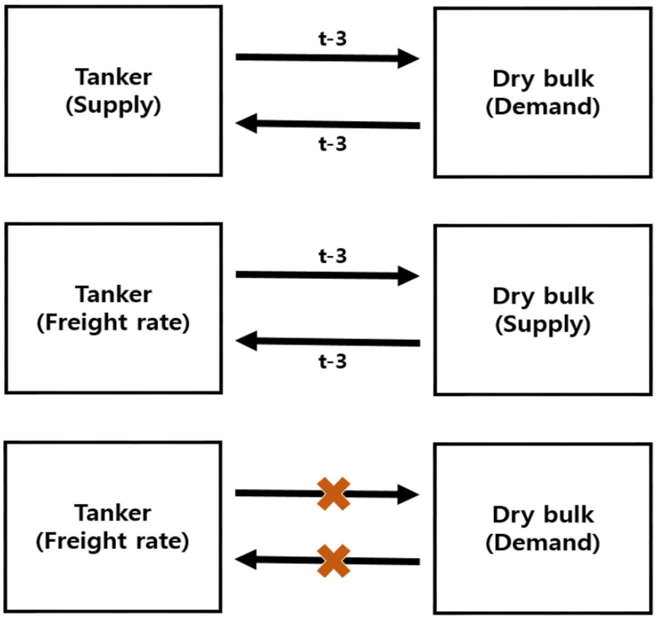
<Fig.21> Causal relationships between dry bulk and container-ship markets



Secondly, this research found strong Granger causality running from demand for bulk trade (China seaborne steam coal exports) to supply of tanker fleet (small tankers fleet development) in the short-run with the lag of 3. However, the inverse Granger causality of the same variables was in the long-run equilibrium relationship with the lag of 3. As well, this study detected strong bilateral Granger causality between supply of bulk fleet (total bulk carrier fleet development) and price of tanker shipping (1-year time charter rate for

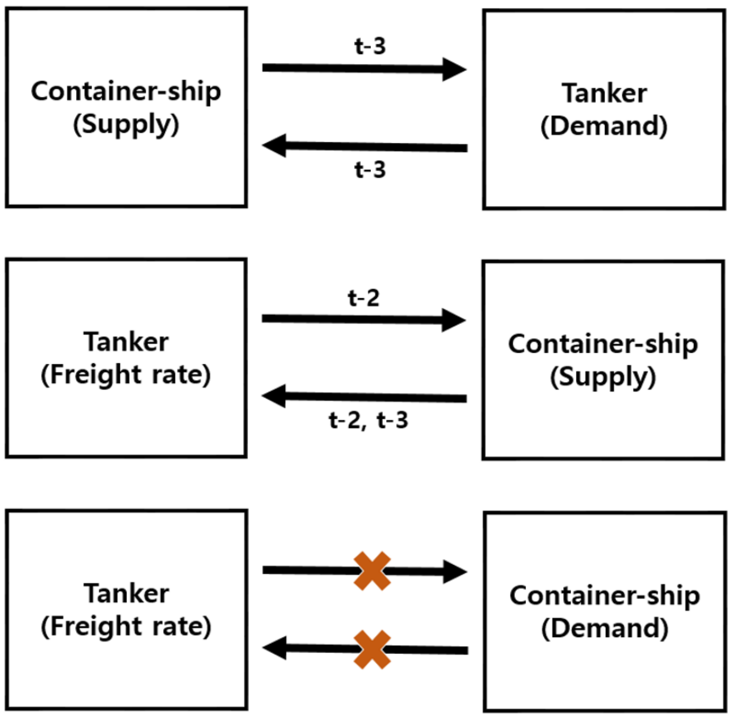
150,000 dwt) in the long-run with the lag of 3. These results clearly indicate that the bulk and the tanker markets cannot be perfectly separated as multipurpose ships which are operated in both markets. When demand for dry bulk trade increases, tanker vessels are converted into bulk ships and *vice versa*.

<Fig.22> Causal relationships between tanker and dry bulk markets



Thirdly, regarding the interrelation between the tanker and the container markets, this study found a strong Granger causality flowing from demand for tanker trade (U.S. seaborne crude oil imports) to supply of container fleet (total container charter owner fleet development) with the lag of 3 and a bidirectional strong Granger causality between price for tanker shipping (1-year time charter rate for 150,000 dwt) and supply of tanker fleet (total container charter owner fleet development) with the lag of 2. It can be analyzed that these results reflect that changes in the tanker market precede changes in the container market since demand for energy commodity tends to increase first during an economic upturn and then demand for raw materials tends to rise.

<Fig.23> Causal relationships between tanker and container-ship markets



Thus, the empirical results confirm the hypotheses that changes in the dry bulk market cause shifts in the container market (Hypothesis II), the bulk and the tanker market are integrated (Hypothesis III) and volatility in the tanker market affects volatility in the container market with the time interval of 2 or 3 months.

5.3 Discussion

This study not only investigated the causal dynamics among demand, supply, and prices within a single shipping market, but also detected the causal relationships among the tanker, the dry bulk and the container-ship markets. This research conducted the Johansen cointegration tests to find the lead-lag relationships among demand, supply, and prices of the shipping markets and estimated VEC models to find the direction of causality and the causality coefficients. This study is the first literature which examined both dimensions of the freight rate mechanism within a single market and the causal dynamics among the three major shipping markets. The contribution of this study to the maritime industry is that this study provides how information of a shipping market flows to another market based on the past values of demand, supply and prices thus it should be helpful to predict change in the conditions of the maritime industry as a whole. This study differs from any literature which conducted correlation tests that a correlation between variables does not statistically mean that change in one variable causes change in another variable. On the other hand, a causality between variables indicate that change in one variable is the result of change in another variable.

However, there are limitations in this study. Firstly, this research did not consider seasonality which is perceived as one of the most important characteristics of the maritime shipping industry. Changes in demand and supply in the shipping markets generally correspond to seasonality. Secondly, there was a lack of enough sample for demand, supply, and freight rates of the container shipping market. The role of container-ship market has been consistently important for the global shipping, as changes in supply and demand for container shipping industry have been proxies of economic booms and recessions. Also, this study did not use shipping indices and earnings as data. Thus, further studies may consider seasonality in analyses and include both shipping indices and earnings as variables to strengthen the empirical results of this study.

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A study of causal dynamics in the maritime shipping markets

국제해운시장의 인과 역학 연구

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요약(국문 초록)

국제 화물 운송에서 해운은 그 담당하는 물량 면에서 절대적인 역할을 하고 있다. 한편 국제해운시장은 국제적으로 완전경쟁시장으로서 선사의 산업에의 진입과 퇴출이 자유로운 편이다. 최근에는 임의적 충격과 구조적인 문제로 인해 해운시장의 시장 여건이 악화되고 있는 상황이다. 임의적 충격은 세계경제의 악화, 주식시장가격의 폭락, 지정학적 충돌의 발생, 에너지 재화의 가격 폭등 등을 포함하며, 구조적 문제는 해운시장을 움직이는 내부적인 메커니즘,

즉 동적 변동을 야기하는 운임체계로부터 발생하는 문제를 의미한다. 해운시장의 운임체계의 바탕이 되는 이론적 배경은 수요-공급 모형이다. 운송시장의 수요-공급 모델에 따르면, 선주는 해운물동량의 변화에 따라 선박공급량을 조정한다. 용선주 또한 해운물동량의 변화에 따라 운임을 조정하지만, 기존 수요를 우선적으로 운송해야 하므로 물동량의 변화에 빠르게 대응하여 선박공급량을 늘리는 것은 쉽지 않다. 궁극적으로, 이는 수요-공급의 불균형을 초래하는데, 선박공급량은 과잉상태가 되어 운임은 급속도로 하락하게 된다. 이는 해운시장에서 수요와 공급의 변화에 대한 정보의 흐름이 시장의 동적 변동에 중요한 역할을 하고 있음을 설명한다. 이와 관련하여, 본 연구는 단일 해운시장에서의 수요, 공급, 운임 간 인과성을 분석하고 또한 주요 3대 해운시장인 유조선 시장, 건화물 시장, 컨테이너 시장들 간의 동태적 인과관계를 분석하였다.

본 연구는 해상운송운임의 결정 요인, 해운 지수와 거시변수 간의 인과성, 그랜저 인과관계 방법론을 다룬 문헌들을 집중적으로 분석하였다. 우선, 해운운임을 결정하는 요소들은 사전에 해운시황을 판단할 수 있는 척도로서 중요한 역할을 한다. 다음으로, 국내총생산, 주식시장 수익률, 산업생산지수와 같은 거시변수와 해운지수는 사이에는 높은 상관관계와 인과성이 나타남을 많은 연구들이 증명하였다. 마지막으로 그랜저 인과관계 검정은 시계열의 안정성 여부를 고려하여 시계열 변수 간 인과관계를 분석할 수 있는 방법론이다. 본 연구는 유조선 시장, 건화물 시장, 컨테이너 시장과 관련된 월간 시계열 자료를 사용하여 그랜저 인과관계 검정을 수행하여 벡터오차수정모형을 추정하였다. 또한, 시계열 변수 간 장기 또는 단기균형관계가 성립하는지 분석하였다. 특히, 본 연구는 중국과 인도의 해운 시계열 자료를 주로 사용하였는데, 최근 10년

간 중국과 인도의 에너지 재화의 수요가 매우 큰 폭으로 증가하였기 때문이다.

본 연구의 범위는 ‘단일 해운시장 내에서의 인과관계’와 ‘복수 해운시장 간의 인과관계’에 집중된다. 우선, 본 연구는 그랜저 인과관계 검정을 통해 유조선 시장 내에서 선박공급량에서 해상운임으로의 강한 인과성을 도출하였다. 또한 건화물 시장 내에서는 물동량에서 선박공급량, 선박공급량에서 운임으로의 강한 인과성을 발견하였다. 그러나 컨테이너 시장에서는 선박공급량에서 해상운임으로만 강한 인과성 도출하였다. 이러한 분석결과는 단일 해운시장 내에서 수요, 공급, 가격이 수요-공급 이론에 따라 상호작용을 하고 있음을 의미한다. 다음으로, 본 연구는 유조선 시장, 건화물 시장, 컨테이너 시장 간의 인과관계를 분석하였다. 컨테이너 해운수요에서 건화물선 공급량, 건화물 해운수요에서 컨테이너선 운임으로 강한 인과성이 나타났다. 그리고 건화물 선박공급량에서 유조선 운임으로도 강한 인과성이 나타났다. 마지막으로, 유조선 해운수요에서 컨테이너선 공급량으로 강한 인과성이 드러났고, 컨테이너선 공급량에서 유조선 운임으로도 동일한 인과성을 도출하였다. 이러한 실증결과는 해운시장은 완전히 분리된 시장이 아니고 통합된 시장으로 판단될 수 있음을 나타낸다. 또한 수요, 공급, 가격 간 장기적 인과관계는 시계열 변수 간 공적분 관계가 나타날 때 도출 가능하였다. 시계열 변수 간 공적분 관계는 시계열 간 장기균형관계가 나타남과 동시에 통합되어 있음을 의미한다.

본 연구는 기존의 문헌에서 분석한 해상운임 결정요인들 간의 인과성을 다시 검토하여 해운시장에서 수요와 공급의 조정에 따라 해상운임이 변화함을 확인하였다. 또한 본 연구는 해운시장이 장기적으로 서로 밀접한 관계를 가지며 동조하는 특성을 분석하였으며, 그 결과로부터 해운시장에서의 변동이 발

생하는 시점과 방향성이 가지는 중요성을 밝혔다. 본 연구는 국제해운시장에 대한 연구의 중요성을 확인하였으며 향후 해운시장에 대한 보다 구체적인 연구의 기초자료로 사용될 수 있을 것으로 기대한다.

주요어: 해운시장, 공적분, 벡터오차수정모형, 그랜저 인과관계

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