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Shipping Economics Development: A Review from the Perspective of the Shipping Industry Chain for the Past Four Decades

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Abstract: To know the development of shipping economics, it is meaningful to overview shipping economics systemically from the perspective of markets and the shipping industry chain. To stimulate future research, this article presents an introduction to the evolution of research models including static models, dynamic models and networks theory, the characteristics of shipping markets including volatility, seasonal and market cycle, and a comprehensive review of the development of shipping economics in the past four decades. We review shipping economics in the following steps: single market's research is generalized including the freight market, financial market including FFA market and investment market, shipbuilding market, and secondhand market; two markets' correlation, information transmission, spillover effects, and other rules in shipping markets are surveyed; the correlation and risk of multi-markets are also investigated. Then, we summarize relationships of the shipping industry chain. Finally, we figure out issues in this field that need further study.
Key words: shipping economics, market characteristics, single market, shipping industry chain
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0 Introduction

Since ancient times, shipping has played an important role in the international trading. Past years have witnessed more than 80 percent of the total international trade volume via marine transportation. Shipping economics as a vital part of international economics has been studied by researchers in the past[1-3]. Shipping economics takes the shipping market as the research field, and the shipping economic relations and economic laws as the research objects[4]. Existing reviews mainly focus on the single shipping markets, including the freight rates, ship prices, and Forward Freight Agreement (FFA). To systematically deduce the research progress of the shipping industry chain as a whole and its internal relevance, we collate and induce the evolution of shipping economics research methods and show shipping economics tests and verify these mathematical methods.

Academically, shipping markets are marketplaces in which related entities complete market activities such as commodity trade, maritime transportation, and investment. The freight market is the most crucial part of shipping markets. It has been put under the spotlight in the past four decades, due to its unique cyclicality, volatility, and unpredictability.

The research in shipping markets has experienced three epochs, including single market, two markets, and multi-markets, while approaches evolve from static models to dynamic models, and to the latest networks theory[5-6]. Shipping markets have many characteristics which are useful to gain profit such as seasonality, price volatility, and market cycle[7-8]. Many works focus on properties of single market in shipping markets, including the freight rate forecast[9], risk hedging in the FFA market[10], strategies of the investment market[11], and valuation of new and secondhand ships[12]. Since single market method cannot analyze relationships among markets, and only provides limited information of the whole shipping markets, many studies propose their insights on the correlation between two markets like the relationship between oil prices and tanker freight and the relationship between ship prices and freight rates[13-15]. Although models for two markets endow the economists with a better understanding of shipping markets' activities, they still over-simplify realistic scenarios and are unable to meet industrial requirements. To this end, the correlation among more markets has

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become a research hotspot these years. Alizadeh and Nomikos[16] investigated the relationship among the oil future market, spot market, and tanker freight market. Alexandridis et al.[17] identified the latent correlation among the freight market, FFA market, and financial market. Studying shipping markets as a whole helps to analyze the inter-correlation of each market and the coupling relationship of entire shipping markets.

This article has three main contributions. ① We summarize the evolution of shipping economics models, from static models to dynamics models, and networks theory. ② We review the development of the shipping economics in the past four decades from the perspective of the shipping industry chain. ③ We propose a method framework to analyze the relevance of various markets in shipping markets based on the theory of equilibrium price.

1 Overview of the Development of Shipping Economics Models

The theoretical progress in different disciplines such as econometrics and complex systems has promoted the development of research on shipping economics. The developed models in these interdisciplinary provide researchers with the opportunity to study the characteristics and rules of the larger and more interconnected shipping markets[18]. We classify and draw the evolution of shipping economics models in Fig. 1 and their time distribution in Fig. 2, based on the literature in the recent forty years. Simultaneously, the development of shipping economics tests and verifies modern mathematics methods and promotes them to become more scientific and practical.

Early shipping economists usually applied structural models to study the static properties of shipping markets. The structural equation (SEQ) model is the work first introduced in this field, which analyzes shipping markets' static structure and freight rate. SEQ is suitable for processing the "strictly" stationary stochastic process, which means that its properties are unaffected by a change in its time origin. The Beenstock and Vergottis (BV) model systematically explains the interaction of the freight, secondhand, shipbuilding, and demolition markets[19]. Consequently, it outperforms most other structural approaches. Structural models often provide a good presentation on static optimization, whereas shipping markets are dynamic. These approaches are unable to address the non-stationary time series and the frequently updated market data, thus not applicable in some cases. Because freight rates and ship prices have many dynamic characteristics such as volatility, seasonality, and cyclicity, their time series are non-stationary. Static methods such as SEQ and BV models are not applicable in non-stationary time series.

Dynamic models describe the market evolving progress which is used to solve non-stationary time series. Besides, dynamic models are gradually applied to solve the false regression, short-term time series, and large lag order. The vector autoregression (VAR) model, which had been leveraged in economics in the 1980s[20], is the model first addressing dynamic markets. Nevertheless, the VAR model's explanatory variables sometimes face a false regression problem in non-stationary time series. To address the problem, Engle and Granger[21] proposed the cointegration theory. The cointegration system could be represented by the VAR model and it built a strong connection between the VAR model and the long-term equilibrium economic theory[22]. Describing freight dynamics is also difficult for most traditional econometric models. The autoregressive conditional heteroscedasticity (ARCH)[23] handles the short-term freight volatility. However, a large lag order of the ARCH would increase the difficulty of calculation. The generalized autoregressive conditional heteroscedasticity (GARCH) model[24] solves the problem by introducing a variance expressed by the combination of the autoregressive moving average (ARMA) model and the ARCH model. The GARCH family is now widely applied to the study on the volatility of the freight market[25], and the correlation between two markets[26].

Apart from external intervention, the liquidity of shipping markets may also introduce small-scale volatility. The wavelet analysis works efficiently on the noisy data with little cost[27]. It can effectively reduce the noise in the raw time series[28], and eliminate the impact of random events[29]. In most cases, the diversity of time series in shipping markets brings many problems, e.g., heterogeneity, noise, non-linearity, and data fusion. Benveniste et al.[30] introduced the multiscale system theory to solve these problems, based on their study on the sequential characteristics of different time series. Nowadays, the multiscale analysis has a wide application in investigating the correlation between tanker freight and oil prices[31], commodity information overflow[32], shipping credit flow data analysis[33], etc.

Compared with dynamic models, networks theory can solve multi-scale market issues better. Thus, it can better deal with the more complex time series brought by the higher frequency, longer time, and multi-markets' correlation. With the revival of artificial intelligence, artificial neural network (ANN) has been frequently applied to shipping economics[34], especially in the freight rate forecast task. When predicting the Baltic Dry Index (BDI), the ANN model has even comparable performance with the autoregressive integrated moving average (ARIMA) and GARCH models. For the freight forecast on different periods, ANN and traditional economics models have their own merits[35]. The theoretical breakthrough on complex networks provides the opportunity to study shipping markets as a whole. An et al.[36] analyzed the global and local structures of shipping markets based on complex networks. Chen et al.[14] had a glance into the dynamic characterization of multi-scale cross-correlation relationships of shipping markets.

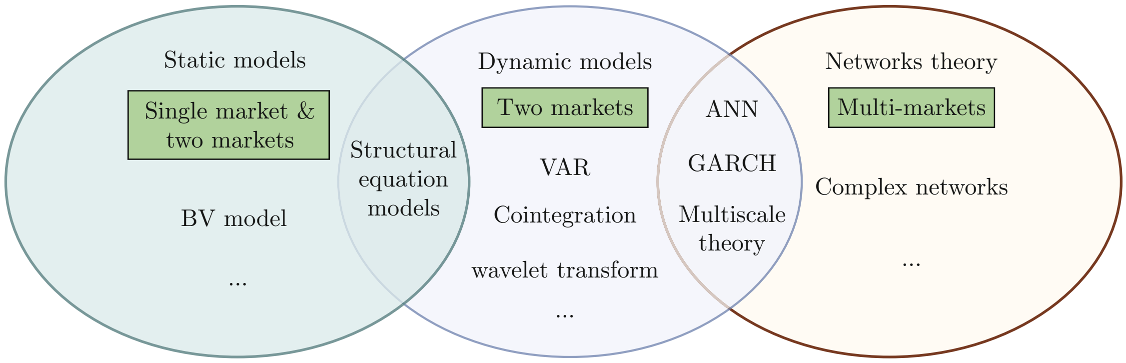

Fig. 1 Shipping economics models' evolution

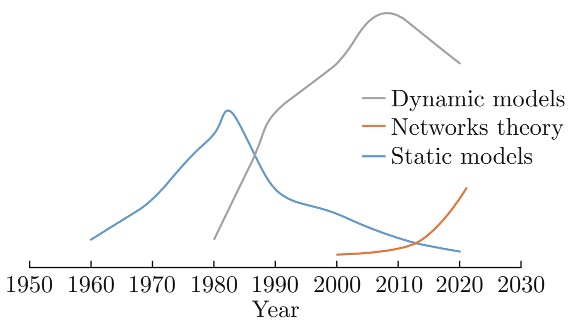

Fig. 2 Approaches' time distribution

2 Shipping Markets' Development and Market Characteristics

2.1 Single Market

In shipping markets, the most important market is the freight market in which freight rate is decided. What's more, the financial market, shipbuilding market, and secondhand market are all important to research the operation of shipping markets. The following contents in this section review the relevant literature of single market in shipping markets. And the research result of shipping markets is shown in Fig. 3.

2.1.1 *Freight Market*

The freight market is a marketplace where the maritime transport is bought and sold. There are two different types of transactions in the freight market. Transport sold at a fixed price is described by the spot rate while the time charter demonstrates ships hired by the day.

Many methods can improve the accuracy of freight forecasts, e.g., ANN, judgmental forecast method, and Delphi method. Lyridis et al.[9] used neural networks to analyze the freight rate of very large crude carrier (VLCC) from October 1979 to December 2002. The result shows that the ANN has comparative advantages to the naïve model. The judgmental forecast method and the combination of ARIMA and VAR are applied in forecasting freight rates in uncertain environments[37-38]. More studies, e.g., the combination of ARIMA and ARCH models[39], and the combination of wavelet transform and support vector machine (SVM) model[29,40], creating a fear index that takes the sentiments of investors and ship owners into account[41], all proved to improve the accuracy of freight forecasting to varying degrees. More than that, considering route-specific, different shipowners and different freight rates could all improve the accuracy of freight forecasting[42].

2.1.2 *Financial Market*

(1) The FFA market. FFA is a promise to sell or buy a commodity (freight service) on the settlement date which can transfer the risk of freight volatility to investors in the freight market. Kavussanos and Nomikos[43] proved that FFA has the function to discover information and price. As improving the accuracy of FFA valuation has positive effects on the price discovery and risk hedging, VECM-SURE (seemingly unrelated regressions estimation) model and exponential mean-reverting model were built to study the volatility of FFA and its estimation[44-45]. Besides, adding a second random factor to the FFA valuation model[46], improving the traditional lognormal representation into a jump-diffusion model[47], and using the relationship between the spot rate and FFA[48] all evinced the improved accuracy of the FFA prediction. The uncertainty resulting from FFA volatility brings difficulty to the risk hedging of the freight market. The uncertainty motivates the study on the volatility of FFA. The volatility of the FFA curve is relatively large, especially one year before the expiry date[49]. Later research figured out that the attributes of shipping companies, hedging time intervals, and FFA deadlines all have an

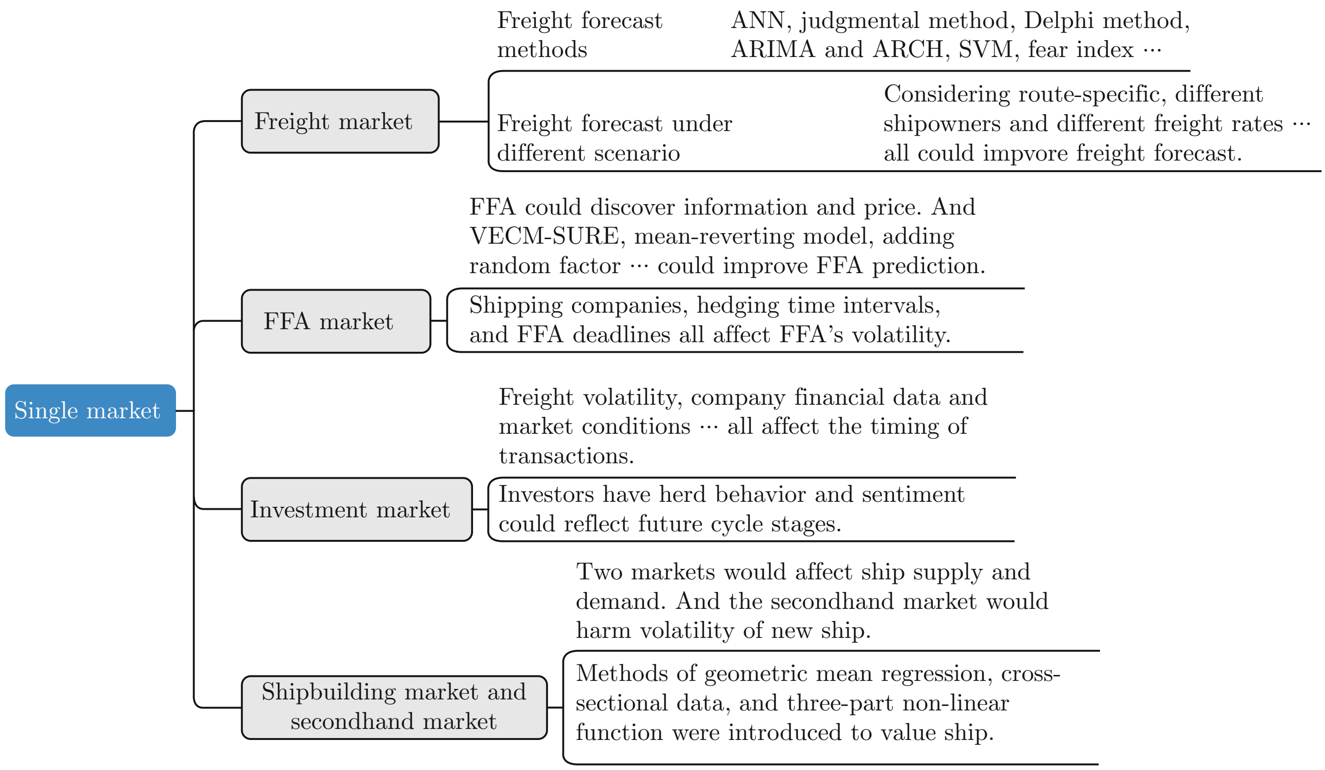

Fig. 3 Single market and research result of different markets

impact on FFA's ability hedging risks[50-51].

(2) The investment market. Investors need to consider many issues when investing, e.g., what kind of investment portfolio to use, when to enter the market, which ship type to buy in, and how other competitors to invest[52-55]. The timing of transactions has obvious effects on investment decisions[56]. Furthermore, some studies reveal that the timing of transactions needs to be determined based on the price-earnings ratio, ship quality[11], freight rate volatility, company stock value, and relationship between freight rates and the market environment[57]. Considering multi-objective and multiple scenarios, evaluating the freight volatility and timing of transactions is better than traditional models[58-59]. Moreover, some studies introduce real option models and market cycles into shipping investment decision-making models in order to evaluate and determine the optimal time of entry[57,60]. The rational and irrational behaviors of investors and shipowners have a significant impact on the investment market. Investors have herd behavior in shipping income and the herd has spillover effects between different shipping sectors[61]. Papapostolou et al.[62] leveraged shipping sentiment indicators that reflect market expectations, ships' valuation, and the liquidity of shipping markets to construct sentiment indexes. Sentiment affects the return of physical assets, and sentiment index is an inverse indicator of future cycle stages.

2.1.3 *Shipbuilding Market and Secondhand Market*

The shipbuilding market, secondhand market, and demolition market determine the supply of ship capacity together[63-64]. Ship demand and ship supply jointly determine the freight rate. Analyzing the influencing factors of ship demand and supply helps to understand the mechanism of freight rates.

The shipbuilding market and the secondhand market both have a great impact on the supply of tankers. Research has found that oil prices and secondhand tanker prices are the main factors that affect the demand for new ships. Concurrently, shelved tonnage and shipbuilding capacity have a greater impact on ship supply than shipbuilding costs. The price of a new ship which fluctuates greatly and has a longer negative shock has the directly effects on the freight rate and ship supply[65-66]. The secondhand transaction volume mainly hurts the volatility of ship prices due to the small liquidity of the secondhand market, limited transaction transparency, ack of ship quotations, and other factors[67].

Secondhand value of a ship is described by a three-part non-linear function: deadweight tonnage (DWT), ship age, and freight market conditions[68]. Considering the uncertainty of freight rate and using cross-sectional data of actual trading transactions in the secondhand market can both improve the accuracy of ship valuation[12,68].

2.2 Market Characteristics

The freight market, financial market, shipbuilding market, and second market all have market characteristics, e.g., price volatility, seasonal, and market cycles[69-71]. Volatility caused by some uncertain factors is common in shipping markets. Shipping markets are seasonal because some commodities are influenced by season. Also, shipping markets have cyclicity due to the herding effect and other factors. The determination of trading timing based on market characteristics is a research hotspot in nowadays' academe. Figure 4 shows research results of volatility, seasonality, and market cycle.

2.2.1 *Volatility*

In recent years, the volatility of markets has drawn significant attention. More and more researchers investigated the latent rules behind the variation. In order to provide a wide-ranging review of the literature, we search for "freight volatility", "shipping volatility", and "shipping fluctuation" in the five databases including Scopus, EBSCO Business Source Elite, Google Scholar, Emerald Collections, and IEEE. Setting the time from 1980 to 2021, we found 141 documents. For these documents, we counted their research methods and drew the research models for shipping volatility, as shown in Fig. 5. For research of shipping volatility, AR model clusters are the most used, in which GARCH has been improved many times. Time series models and structural equation models are also used very frequently. What's more, networks theory has been used gradually on the study of shipping volatility.

From the retrieved documents, we have selected 25 articles that we think are more closely related to the theme to illustrate the research methods and their results. Table 1 shows a part of relevant literature on volatility. The research of shipping volatility mainly focuses on the freight market and the FFA market.

In the last two decades, scientists have gone deep into the study on volatility. The theoretical framework was used to improve the effectiveness of volatility analysis which could reduce the error and filter the relevance of returns[72]. Besides, combining multivariate-fuzzy integrated logical forecasting method (M-FILF) with fuzzy time series (FTS) methods[73-74] and applying multifractal detrended fluctuation analysis (MF-DFA) technology[75] to freight volatility analysis can both improve the effectiveness.

Some literature has studied the factors which affect the volatility of freight rates. The ship size, interaction magnitude between the demand and the supply of shipping capacity, and uncertainty of the shipowner's income were found that they all have different impacts on the volatility of freight rates[76-80]. In addition,

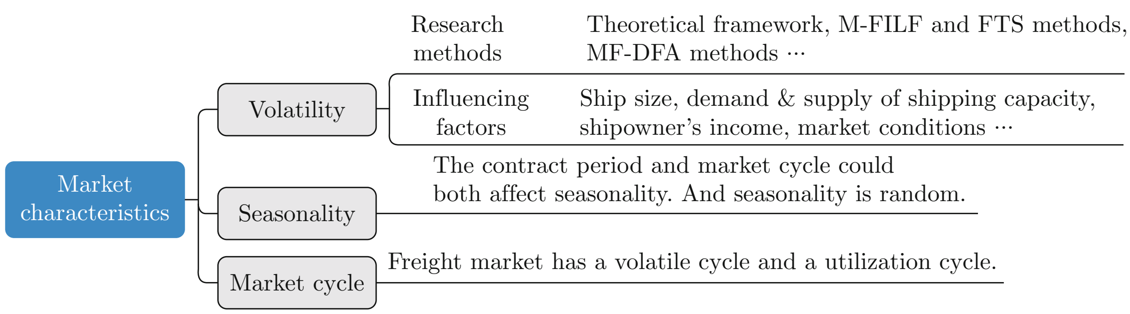

Fig. 4 Market characteristics and their research results

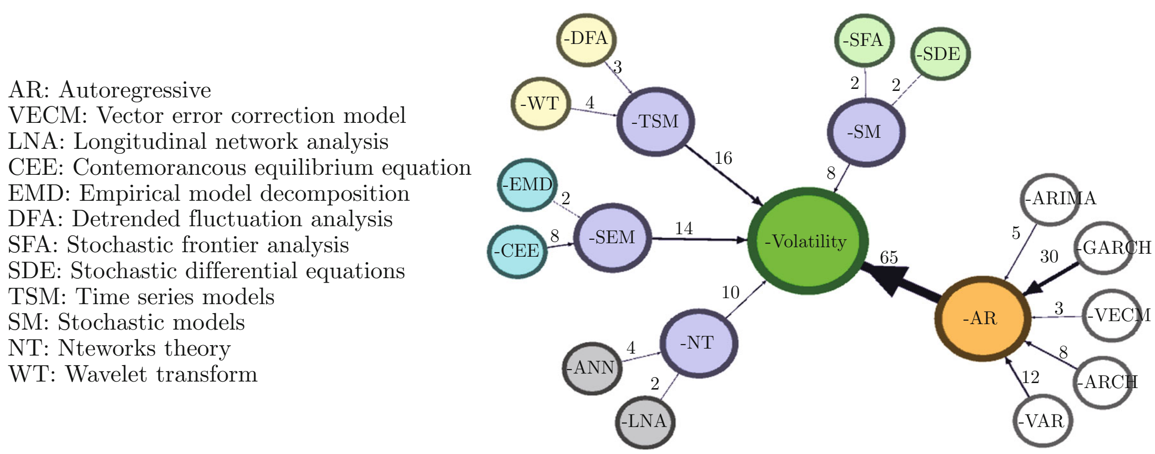

Fig. 5 Research models for volatility

Table 1 Part of relevant literature on volatility

Literature	Method	Finding
Ref. [81]	ARIMA, VAR	The seasonal freight volatility of different ship types varies under divergent contract periods and market conditions.
Ref. [82]	Seasonal ARIMA, VAR	For each ship size of dry bulk, the seasonal volatility is inversely correlated with the contract period.
Ref. [83]	Augmented Dickey-Fuller test	The shipping rate stays relatively flat compared with other metrics.
Ref. [49]	Term structure model	The volatility of the FFA curve reaches the peak one year before the expiry date.
Ref. [76]	GARCH	Leverage has a positive impact on freight volatility especially when the ship is large and the market is on a downward trend.
Ref. [79]	GARCH	The asymmetric characteristics of freight volatility change with different sizes of ships and market conditions.
Ref. [84]	Stochastic differential equation framework	LPG spot freight can be described by a linear random model.
Ref. [72]	Stochastic volatility model	A theoretical framework is established for the maximum volatility risk assessment of dry freight.
Ref. [77]	Instantaneous equilibrium equation	The demand and the supply for transport capacity both influence freight volatility.
Ref. [85]	Mixed system model of dry bulk market	Spot premium shocks under low uncertainty have higher research value than the contrary condition.
Ref. [86]	Multi-state Markov-switching regime	Tanker freight is relatively stable than other metrics.
Ref. [73]	M-FILF with FTS	FTS method outperforms traditional time series methods when addressing time series.
Ref. [87]	Indicators of concentration; GARCH	Freight volatility would increase during the upward and downward periods of the market especially during the upward and downward periods.
Ref. [74]	Empirical model decomposition (EMD) method	EMD provides a clear representation of the characteristics of the freight rate series by reducing residual errors.
Ref. [88]	GARCH (multivariate)	Freight and ship prices have significant conduction effects while freight volatility is the most important factor affecting the price fluctuations of new ships.
Ref. [50]	Bivariate Markov regime switching GARCH model	Three potential causes of FFA's limited performance when hedging the risk of oil rankers are: the existence of residual risks; the insufficient connection between the freight market and the FFA market; the lack of liquidity in the FFA market.
Ref. [89]	Factor model, Kalman-filter methodology	Models allowing for stochastic seasonality outperform models with deterministic seasonality.
Ref. [75]	MF-DFA, detrended fluctuation analysis (DFA)	The multifractal of dry bulk freight rate is due to non-linear correlation.
Ref. [25]	GARCH-X	The accuracy of forecasting the volatility of tanker freight is improved when considering the impact of oil prices.
Ref. [90]	Simultaneous equations Model, three-stage least squares	Market, cost, and operational factors have a considerable impact on the supply of fleet capacity.
Ref. [57]	Augmented Dickey-Fuller test, Phillips-Perron test, Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test	The stability of freight is checked.
Ref. [51]	Cointegration, Portfolio theory, the wild clustered bootstrap	The attributes of shipping companies, hedging time intervals, and FFA deadlines all affect FFA's ability to hedge risks.
Ref. [91]	VECM, VAR model	Capacity indicators can partially explain the changes in freight rates on a weekly basis.
Ref. [78]	Generalized error distribution	There is a positive skewness premium when pricing conditional risk and conditional skewness, and risk spillover effect.
Ref. [92]	AR model	Averaging freight rate is a stable process, which is related to the supply and demand ratio.

freight rates have a positive skewness premium in some cases[78]. Further research found that the asymmetric characteristics of freight volatility change with different sizes of ships and market conditions[79]. Dikos et al.[80] clarified that a larger ship size results in the higher volatility by establishing a system dynamics model.

2.2.2 *Seasonality*

Except for volatility, shipping markets are also seasonal. Seasonal characteristics of the time charter rates are broadly utilized to predict future spot rates. Kavussanos and Alizadeh[81] employed ARIMA and VAR models to analyze the seasonal volatility of dry bulk shipping spot and time charter freight rates. The result shows that seasonal volatility has an inverse correlation with the contract period for each ship size. Also, Markov switching models were used to study the seasonality of the tanker freight market[82]. They found that seasonal rate movements are more pronounced when the market is recovering, compared with smaller changes when the market is falling. Models considering random seasonality outperform those models with deterministic seasonality[89]. Furthermore, the China Containerized Freight Index (CCFI) has obvious seasonal characteristics, peak season of which appears in spring and autumn[93].

2.2.3 *Market Cycle*

The market cycle is driven by the supply and demand of shipping. Since the market cycle is directly correlated with profits, the research in this direction has both theoretical research significance and practical value.

Since the regularity of shipping markets was discovered[8], the cycle of shipping markets has attracted much attention. Further study proves that the bulk freight market follows a typical cycle pattern[94]. With the help of system dynamics, some studies clarify that there are a 20-year volatile capacity adjustment cycle and a 4-year capacity utilization adjustment cycle in the freight market[95-96]. Besides, the cycles of the dry bulk freight, Aframax tanker and container ships show that there is similar market cycle[96-98].

3 Research Development of Shipping Industry Chain

3.1 Two Markets

In recent years, researchers have studied the market characteristics and market rules of the freight market, financial market, shipbuilding market, secondhand market, demolition market, etc. Further research has been conducted on the correlation, information transmission, spillover effects, and other rules between two markets[99-100].

3.1.1 *Freight Markets of Different Ship Types*

Analyzing the relationship between freight markets of different ship types helps investors and shipowners to improve their investment strategies promptly based on relevant events. As early as 1993, Beenstock and Vergottis[101] researched the relationship between the dry bulk market and the tanker market. They believed that the spillover effect between two markets is obvious. When one sector is analyzed, the other sector needs to be analyzed at the same time; otherwise, it is incomplete. On this basis, Glen[102] found that the tanker and bulk carrier markets are co-integrated. But if the common trend factors are random, the result does not mean that the market efficiency is low. Hsiao et al.[103] further investigated the impact of the financial crisis and other shocks on the relationship between dry bulk and container markets. Considering the entire financial crisis and before the financial crisis, the Baltic Dry Index (BDI) and CCFI have no significant lead-lag relationship. During the financial crisis, the BDI is ahead of the CCFI. After the financial crisis, the CCFI is ahead of the BDI.

3.1.2 *Freight Market, Shipbuilding Market and Secondhand Market*

It is meaningful to analyze the interaction among the shipbuilding market, secondhand market, and freight market because of the decisive influence of shipping markets on ship capacity. The study on the relationship between the freight market and the shipbuilding market shows that shipbuilding activities depend on the freight market[104]. The freight rate is more sensitive to market changes than the price of new ships. Another finding[15] indicated that a strong freight market can promote investment in new ships. Besides, freight rates have a positive correlation with the concentration of the shipbuilding market and the secondhand market[87]. Dai et al.[88,105] claimed that Capesize, Panamax, Handymax, and Handysize have significant volatility transmission effects among the shipbuilding market, secondhand market, and freight market. Freight rate volatility is the most important positive determining factor of the price volatility for the four new ship types. Price volatility of secondhand ships is not the decisive factor for price volatility of any ship type.

3.1.3 *Freight Market and Commodities Markets*

The impact of oil prices on the tanker freight market is extremely unquestionable[106-107]. It is hard to figure out the influence of crude oil price on the tanker freight market. Studying the relationship between oil prices and tanker freight rates would improve investment decision-making. The spillover effects among oil prices, crude oil futures, crude oil inventories, and freight rates are obvious. The demand for tankers is a derivative of oil demand[13]. Oil price shocks are mainly divided into supply shocks and non-supply shocks. Crude oil supply shocks have an impact on the tanker market while the impact of non-supply shocks can be ignored[108]. Sun et al.[31] analyzed the multi-scale correlation between freight rates and oil prices based on time correlation. The result shows that tanker freight rates and oil prices exhibit different multi-scale characteristics, especially a significant correlation in the medium and long term. Similarly, the volatility mutation is considered to study the relationship between the crude oil market and the tanker market. Brent's volatility has a greater impact on the tanker market than the WTI market[26]. Zhang[109] further surveyed the time-varying effects of oil prices and the tanker market. The experiments demonstrated that high oil prices reduce the correlation in the tanker market.

Compared with oil tankers transporting crude oil, dry bulk carriers transport more types of commodities, which also provides researchers with more research directions. Kavussanos et al.[110] clarified that there is a significant spillover effect between the FFA market and the commodity derivatives market. They also discovered that new information first appeared in the returns and volatility of the commodity futures market, and then spilled over to the FFA market[111]. Açik and Baser[112] studied the asymmetric causality from iron ore price to the freight market with considering the impact of the financial crisis. Via analysis before and after the crisis and throughout the entire period, the impact of commodity prices on the freight market before and after the crisis is different. They further analyzed and found that the positive and negative shocks in coal and steel prices are symmetrical causes of the positive and negative shocks in ISTFIX[113]. Meanwhile, the negative shocks in wheat prices are causes of positive shocks in the index, and positive shocks in the commodity are causes of negative shocks in the index. From the perspective of the threshold, Melas and Michail[114] found that the relationship between the commodity market and the freight market changes drastically when commodity prices drop sharply. And freight rate is affected more than normal. Michail and Melas[115] firstly classified the relationships between agricultural products and the dry bulk freight market. Commodity prices have a great impact on most types of ships except for rice and soybeans. There is likely to be a strong substitution effect between these two products and there is a certain substitution effect between ship types.

3.1.4 *Freight Market and Other Markets*

The return and volatility of the stock index have slow information diffusion, which can explain changes in freight rates[116]. The temporaneous and bidirectional lead-lag relationships between the freight market and the stock market are stronger in the dissemination mechanism while weaker in the normal regime. Compared with the Chinese stock market, the US stock market can influence shipping markets more sensitively[117]. Besides, the positive shocks of international geopolitical risk have a positive impact on freight rates but gradually weaken. And the positive shocks of economic policy uncertainty usually harm freight rates[118].

3.2 Multi-Markets

Researchers have carried out much analysis on the correlations and the risk propagation among multiple markets, revealing the laws and market characteristics of the shipping industry chain.

3.2.1 *Correlation of Multi-Markets*

The shipbuilding market, secondhand market, and demolition market are interrelated with the freight market. Adland et al.[119] firstly analyzed the instantaneous equilibrium relationship between the real secondhand ships' values and the values of secondhand ships implied by the shipbuilding market and the freight market. Lun and Quaddus[120] further studied the relationship among the ship prices, fleet size, freight rate, and commodity trade volume in shipping markets. The result shows that the commodity trade volume has a significant impact on the fleet size, while the fleet size is also affected by freight rates. Besides, the freight rate has a great impact on ship prices. What's more, Michail and Melas[121] investigated the impact of the commodity trade volume on the freight market. The commodity trade volume has a great impact on the dry bulk freight and the dirty tanker freight while it has little effect on the clean tanker.

Futures markets respond to information dissemination faster than the spot market. Alizadeh and Nomikos[16] analyzed the correlations among oil spot, oil futures, and tanker freight, indicating that the difference between crude oil spot price and futures price reflects the transportation cost which is mainly fuel price. Nevertheless, there is no correlation between the tanker freight and the price difference of crude oil spot and futures. Sun et al.[122] had a further study on the relationship among crude oil futures, fuel futures, and FFA. In line with their conclusion, the crude oil futures market is the main information transmitter of the other two futures markets. The fuel futures market plays a role in buffering, dissemination, and reception. FFA market is an information recipient and its response to shocks of crude oil futures varies with market conditions. Alexandridis et al.[17] investigated the relationships among time charter rate, freight futures, and freight options. In terms of information, freight futures are ahead of the time charter market while freight options lag freight futures and time charters.

3.2.2 *Risks of Multi-Markets*

The risks of shipping industry are decided by capacity supply and capacity demand. Once the systemic risk of the shipping industry chain occurs, it will be transmitted to other markets in the industry chain through price fluctuations. The correlation among different markets causes the spread of systemic risks to be more rapid. Zhang and Zeng[45] used complex network methods to analyze the spread of systemic risks among the shipbuilding market, secondhand market, freight market, and shipping stocks under the influence of the financial crisis. They found that different markets are more closely connected during the financial crisis. Adland and Jia[65] established the contemporaneous equilibrium model of the shipbuilding market, secondhand market, demolition market, and freight market. According to the findings, the lower volatility of new ship prices is due to the time-varying delivery lag. And this is positively correlated with the alternative cost of operating in the freight market. Further, Zhang and Zeng[45] decomposed the time series of tanker freight rates in order to study the volatility spillover effects among the three tanker freight rates. The result shows that the spillover effects of the original series are not significant while the spillover effects are obvious among the components.

3.3 Relationships Among Shipping Industry Chain

Based on the theory of equilibrium price[123], capacity demand and capacity supply determine the spot rates and time charter rates. According to the concepts listed above and the literature investigation, we summarize the relationships in shipping industry chain, as shown in Fig. 6, where the thickness of the arrow indicates the relative size of the cash flow. We use the relationships of shipping markets as the analysis framework to study the rules and characteristics of shipping markets.

Shipping markets consist of the trade market, freight market, financial market, shipbuilding market, secondhand market, and demolition market, where the freight market usually includes the spot rate market and the time charter market. FFA is the main component of financial market. The participants in shipping markets involve shipowners, shippers, and shipyards. The shipper generates demand for capacity after completing the commodity transaction. Then shippers deliver goods to carriers and carriers are responsible for transporting the goods in which carriers can be shipowners or charterers. The shipbuilding market, secondhand market, and demolition market influence each other and determine the capacity supply together. Besides, investors determine investment strategies in the financial market and use FFA to hedge risks.

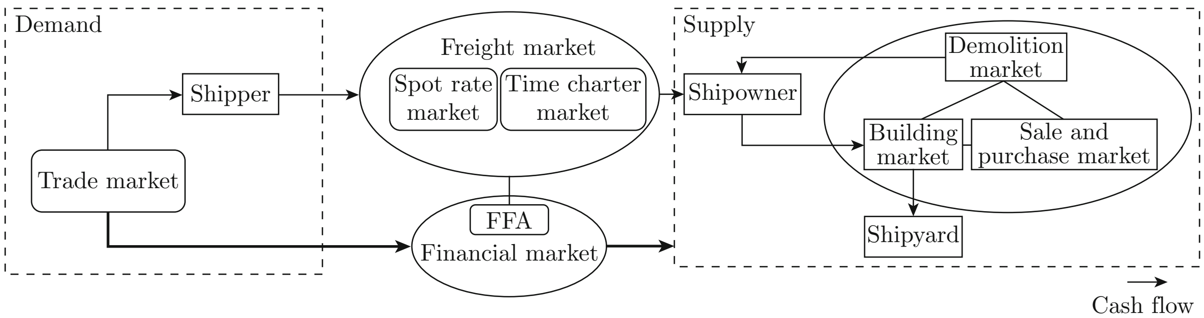

Fig. 6 Relationships in shipping industry chain

4 Conclusion

This article first briefly discusses the background, composition, and interrelationship of shipping markets. Then we introduce the evolution of the main measurement models of shipping economics including static models, dynamic models, and networks theory. Static models include SEQ models, BV models, etc., which are applied in single market and two markets. Dynamic models include VAR, cointegration, GARCH, wavelet transform, multiscale theory, etc. And dynamic models are mainly used to solve non-stationary time series, volatility analysis, freight forecast, and so on. Networks theory which is applied in multi-markets consists of ANN, and complex networks. Furthermore, this article reviews market characteristics and the development of shipping economics in the past four decades. We summarize the process from the perspective of characteristics of single market and the relationship of two markets, and the correlation and risk of multi-markets. For single market, we summarize the gain of freight forecast, function and volatility of FFA, timing of transaction, and effect of the shipbuilding market and the secondhand market on ships' demand and supply. For two markets, we review the correlation, information transmission, and spillover effects between two markets. As for multi-markets, we conclude the correlation and risk spread of multi-markets. At last, we deduce and induce relationships among shipping economics.

For future research, it is meaningful to expand from the following aspects.

(1) The local characteristics of shipping markets may be more in-depth. More research can be conducted under the constraints of different market environments or specific routes and specific ship types in the future. At the same time, the research can try to combine different models to study market characteristics in more detail. Besides, more attention may be paid to study the relationship between two markets when meeting an outside impact such as a financial crisis.

(2) The correlation and risk spread of the shipping markets may need to be analyzed from the entire system. It is inaccurate enough to consider only the impact of single market on freight rates. It is more thoughtful to study the shipping markets from the perspective of multi-markets and shipping industry chain. The risk of single market would spread to the entire shipping markets, which would grow into a systemic risk. Thus, the study of market risk may need to consider systemic risks from the perspective of the industrial chain. Besides, how the risk spreads in the industry chain when great shocks occur and how the industrial structure changes when the risk reaches the threshold would become the research hotspots.

(3) Complex systems theory, especially the complex networks theory would become a powerful tool to study the shipping industry as a whole. If the shipping industry chain is studied as a whole, the amount of

calculations is huge. The development of complex networks theory provides the possibility to reduce dimensionality and retain effective information. Research on the freight rate, freight volatility, and risk spread will become the trend under the network framework of the shipping industry chain from the top-down viewpoint. Also, simulation research from the perspective of the bottom-up will provide another way for the shipping markets.

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