

# Modeling the determinants of dry bulk FFA trading volume from a cross-market perspective of spot and forward

Shiyuan Zheng and Shun Chen

*School of Transportation, Shanghai Maritime University, Shanghai, China*

## Abstract

**Purpose** – This study aims to propose a theoretical model to characterize the optimal forward freight agreement (FFA) procurement strategies and investigate the determinants of FFA trading activities from a new cross-market perspective.

**Findings** – A two-step model specification is used to empirically test the theoretical results for the Capesize, Panamax and Supramax sectors. It is found that spot demand has a positive relation with FFA trading volume for all three sectors. Moreover, spot demand volatility has a negative relation, while the correlation between spot demand and spot rate has a positive relation with FFA trading volume for the Capesize and Panamax sectors.

**Originality/value** – The results show that the expected spot demand is scaled by a “quantity premium,” which is the product of a demand covariance term, a demand riskiness term and a demand volatility term. This can be used by the traders in the FFA market to construct their hedging strategies.

**Keywords** Trading volume, DCC-GARCH model, Dry bulk, FFA, Fixture demand, Spot price

**Paper type** Research paper

## 1. Introduction

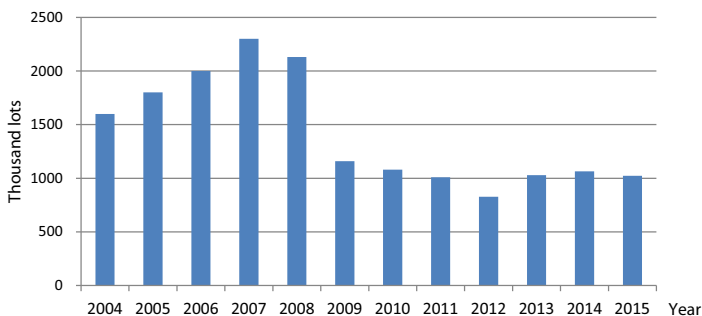
Since the past 20 years, the forward freight market has experienced a dramatic change. After reaching a historical peak in 2007, its trading volume sharply decreased in 2008 and 2009, then maintained at a relatively stable level around one million lots in the recent six years (except 2012, see [Figure 1](#)). As an important hedging tool, the forward freight agreement (FFA) plays a significant role in risk management in the dry bulk and tanker markets. An FFA is defined as a cash-settled contract between two counterparties to settle a freight rate for a specified quantity of cargo or hire rate type of vessel in one or a basket of the major shipping routes in the dry bulk and tanker shipping sectors at a certain date in the future ([Alizadeh et al., 2015a](#)). Because of its remarkable value for the shipping theory and the industrial practice, FFA draws much attention in the academic field. However, the FFA market has long been dominated by financial institutions such as hedge funds and investment banks, which treat the FFA as a speculation tool. In this paper, we aim to investigate the hedging function of FFA and the determinants of the FFA trading volume for the dry bulk shipping sector from a cross-market perspective (the spot market and the future market). Through this study, we examine whether the FFA can play a hedging and risk management role or only as a speculation tool.



There are lots of studies on the dynamics of the FFA market, the relationship between spot rates and FFA prices and risk management issues related to FFA. [Kavussanos and Visvikis \(2006\)](#) make a survey for the literature on shipping derivatives including FFA. For the issue of the dynamics of the FFA market, most studies investigate the volatility of FFA prices or returns and their influencing factors. [Koekebakker and Ådland \(2004\)](#) use the weekly time charter rates of a Panamax 65,000 dwt bulk carrier as a sample to investigate the factors governing the dynamics of the forward freight rate curve. [Batchelor \*et al.\* \(2005\)](#) explore the interrelationships between the bid-ask spreads and the FFA price volatility. [Kavussanos \*et al.\* \(2010\)](#) examine the cross-market linkages and spillover effects between FFAs and futures contracts on the commodities carried by Panamax vessels. [Kavussanos \*et al.\* \(2014\)](#) investigate the economic spillovers between the freight derivatives markets of the dry bulk shipping sectors and the derivatives of the commodities carried by the dry bulk vessels.

For the issue of relations between spot rates and FFA prices, [Kawssanos and Nomikos \(1999\)](#) examine the relationship between the futures prices and the realized spot prices in the Baltic International Freight Futures Exchange (BIFFEX) market. [Kawssanos and Nomikos \(2003\)](#) examine the causal relationship between futures and spot prices in the freight futures market. [Kavussanos and Visvikis \(2004\)](#) use the vector error correction model (VECM)-generalized autoregressive conditional heteroskedasticity (GARCH)-X model to examine the lead-lag relationship in both returns and volatilities between spot and FFA prices for four Panamax routes. [Kavussanos \*et al.\* \(2004a\)](#) investigate impacts of the introduction of the FFA trading on the spot price volatility. [Kavussanos \*et al.\* \(2004b\)](#) use the same four routes as a sample to investigate whether the FFA prices (one, two and three months before maturity) are the unbiased predictors of spot rates. [Batchelor \*et al.\* \(2007\)](#) compared the performance of vector auto regression (VAR), VECM and autoregressive integrated moving average models in forecasting spot and FFA rates. The results indicate that FFA prices can improve the forecasting performance of spot prices, but not vice versa. [Tezuka \*et al.\* \(2012\)](#) establish an equilibrium price model to derive the spot price and future price formulae. Moreover, they obtain an optimal hedge ratio based on their model. [Zhang \*et al.\* \(2014\)](#) explore the lead-lag relationships in freight rates between spot and forward markets. [Li \*et al.\* \(2014\)](#) use dynamic conditional correlation (DCC)-GARCH model to investigate the spillover effects and dynamic correlations between spot and forward tanker freight rates returns.

For the issue of FFA hedging and risk management, [Tvedt \(1998\)](#) derives an analytical pricing formula for European futures options in the BIFFEX market. [Kawssanos and](#)



Source: Baltic Exchange

Figure 1. The annual FFA trading volume in the dry bulk shipping market

Nomikos (2000a, 2000b) investigate the hedging ratios and hedging efficiency in the BIFFEX market. Dinwoodie and Morris (2003) utilize the questionnaires to study the attitudes of tanker shipowners and charterers toward freight hedging and their risk perceptions of FFAs. Koekebakker *et al.* (2007) establish theoretical models to value the Asian-style options traded in the freight derivatives market. Nomikos and Doctor (2013) carry out a comprehensive study on the quantitative trading strategies in the FFA market for various contracts and maturities with different trading rules. Alizadeh *et al.* (2015a) investigate the impact of liquidity risk on FFA returns. Alizadeh *et al.* (2015b) examine the effectiveness of alternative hedging methods in managing tanker freight rate risk based on Tanker FFAs.

Although there are many studies concerning different aspects of the FFA market, there are very little research examining the relationship between the FFA trading volume and its determinants from a cross-market perspective. Here, we focus our attention on the work of Alizadeh (2013), who investigate the relationship between the FFA trading volume and FFA price volatilities for Capesize, Panamax and Supramax sectors. In our paper, we aim to explore the hedging function of FFA and the determinants of the FFA trading volume from a different cross-market perspective. Although we work on a similar topic, there are still some differences as follows:

- *Different perspectives:* Alizadeh (2013) explores the relation between the FFA trading volume and its price volatility in the FFA market, while we investigate the impacts of the spot demand volatility and the covariance between the spot rate and the spot demand, or the covariance between the earning and the spot demand, on the FFA trading volume. In other words, we mainly focus on the FFA hedging from a cross-market perspective, while Alizadeh (2013) examines the speculation or arbitrage of FFA. To be consistent with the fact that many players in the practice trade FFA for the purposes of speculation or arbitrage, we add the consideration of the speculation or arbitrage function of FFA in our empirical studies. Still, we find that the demand volatility in the spot market has a negative impact on the FFA trading volume, while the covariance between the spot demand and the spot rate can influence positively the FFA trading volume for the Capesize and Panamax sectors.
- *Different theoretical basis:* Alizadeh (2013) uses the theory of the mixture of distribution of Clark (1973) to explain the contemporaneous relationship between volatility and trading activity, while we establish a model on the inventory theory to characterize the equilibrium of the FFA trading activity and its determinants.
- *Different models to estimate the volatility:* Alizadeh (2013) uses the EGARCH-X model to estimate the FFA price volatilities, while we use the DCC-GARCH to estimate the time-dependent spot demand volatility and the covariance between the spot demand and the earning, as well as the covariance between the spot demand and the spot rate. In the DCC-GARCH model, asymmetries are incorporated in a broader fashion than in other types of multivariate GARCH models, i.e. the DCC-MGARCH model does not assume constant correlation coefficients over the sample period. Specifically, it allows for series-specific news shocks and smoothing parameters and takes into account conditional asymmetries in correlation dynamics and corrects for heteroskedasticity directly by using standardized residuals in the estimation of correlation coefficients (Tsouknidis, 2016). Therefore, the dynamic variance and covariance needed to verify our theoretical statements can be better estimated.

Our work contributes to the literature in the following ways.

Theoretically, we investigate the FFA hedging function and the determinants of dry bulk FFA trading activities from a new cross-market perspective. Some existing literature explores the determinants of FFA trading volume from the freight forward market itself, e.g. FFA price volatility and FFA trading volume (Alizadeh, 2013). Others discuss the relationship between prices in the spot and forward markets (Kavussanos and Visvikis, 2004; Kavussanos *et al.*, 2004a, 2004b; Batchelor *et al.*, 2007; Tezuka *et al.*, 2012; Zhang *et al.*, 2014), or the volatility spillovers (Kavussanos *et al.*, 2014; Tsouknidis, 2016), from a cross-market perspective. In our paper, we propose a theoretical model to characterize the optimal FFA procurement strategies to indicate the FFA hedging function. We prove that the optimal FFA procurement quantity is the expected spot demand scaled by a “quantity premium,” which is the product of a demand covariance term, a demand riskiness term and a demand volatility term, from the perspective of hedging. We argue that besides FFA prices, some factors in the spot market, e.g. spot rates, spot demand, spot demand volatility and the covariance between the spot demand and spot rate, have impacts on the FFA trading volume.

Empirically, we link our study with the existing literature which mostly examines the dynamic of the FFA prices. Considering both the hedging and the speculation functions of FFA in the empirical studies, our theoretical conclusions are tested and most of them are verified in the Capesize and Panamax sectors. The empirical study results indicate that our investigation on the FFA hedging from a cross-market perspective is valid. Moreover, our empirical studies illustrate the procedure to obtain the parameters needed to determine the optimal FFA procurement quantity when using the FFA hedging function. The empirical equations between the FFA trading volume and its determinants can be used for the possible applications of the FFA hedging.

The rest of the paper is organized as follows: Section 2 establishes a theoretical model to characterize the optimal FFA procurement strategies for a buyer. Section 3 uses a two-step model specification to empirically test the theoretical statements derived from Section 2. Conclusions and possible directions for future research are summarized in Section 4.

## 2. Theoretical model

In this section, we establish a theoretical model to analyze the shipping capacity procurement problem when a buyer faces uncertainties in the spot demand, spot rates and shipping revenues. It is worthy pointing out that our theoretical model focuses on the hedging function of FFA[1]. It is well known that shipping capacities cannot be stored. Thus, procurement of shipping supply in the spot and forward markets for delivery on the usage date is important in matching a buyer’s uncertain demand. Our model can characterize the optimal FFA procurement strategies for a buyer. In our model, a buyer is an agent who uses the shipping services, e.g. a shipper. To hedge the risk of the spot rate fluctuation and the uncertain demand in the future, he procures some shipping capacities now by a forward contract with delivery at a future time (of course, in any time before its delivery, he can sell them in the market if it is profitable to do so. This can be considered as the speculation or arbitrage function of FFA). Because the international dry bulk shipping is a perfect competition industry (Pirrong, 1992), the sum of all buyers’ optimal FFA procurement quantities is the market equilibrium volume. Therefore, we can investigate the determinants and their impacts on the FFA trading volume by our model.

We consider a shipping capacity procurement problem in a finite horizon  $[0, T]$ . To satisfy a shipping demand at time  $T$ , the buyer decides to procure  $q$  units of shipping capacity at time 0 in a forward contract with delivery at time  $T$ . It could be argued that FFAs are cash-settled instruments without any obligation whatsoever to deliver a transport

service. However, if we consider a FFA's hedging function, we could relate the FFA's trade with the transport service. According to the definition of FFA, it settles a freight rate for a specified quantity of cargo at a certain date in the future. That means that the FFA's trader tries to avoid the future fluctuation of the freight rate using the FFA contract. When he sells the FFA contract, the buyer implicitly undertakes the transfer of the transport services. The FFA contract price is  $F$  at time 0. The shipping demand  $D$  is a random variable at any time before time  $T$ , and it becomes known at time  $T$ . The spot shipping price  $f$  and the buyer's marginal revenue  $r$  to fulfill the shipping business at time  $T$  are random variables too. Thus, the buyer faces the following optimization problem:

$$\max_q \pi = E[r\min(q, D) + f(q - D)^+ - Fq] \quad (1)$$

where  $(\cdot)^+ = \max(\cdot, 0)$ ,  $\pi$  is the buyer's profit and  $E$  is the mathematical expectation.

The first and the second terms in [equation \(1\)](#) are the buyer's expected revenue from shipping and selling the excess capacity on the spot market, respectively. The third term in [equation \(1\)](#) is the buyer's forward procurement cost. Therefore, the buyer faces a stochastic optimization problem to determine his best procurement quantity in the forward market. Similar models can be found in the trade of future commodity, e.g. natural gas ([Secomandi and Kekre, 2014](#)).

Note that  $F$  is known by the buyer and  $D, f$  and  $r$  are unknown to the buyer when he makes the procurement decision. To solve [equation \(1\)](#), we assume the demand  $D$ , the buyer's marginal revenue  $r$  and the chartering price  $f$  to follow the joint lognormal distribution[2]:

$$\begin{pmatrix} \log D \\ \log r \\ \log f \end{pmatrix} \sim N \left[ \begin{pmatrix} \log M_D - S_D^2/2 \\ \log M_r - S_r^2/2 \\ \log M_f - S_f^2/2 \end{pmatrix}, \begin{pmatrix} S_D^2 & \rho_{Dr}S_D S_r & \rho_{Df}S_D S_f \\ \rho_{Dr}S_D S_r & S_r^2 & \rho_{rf}S_r S_f \\ \rho_{Df}S_D S_f & \rho_{rf}S_r S_f & S_f^2 \end{pmatrix} \right] \quad (2)$$

where  $M_D, M_r$  and  $M_f$  and  $S_D, S_r$  and  $S_f$  are the mean values and standard deviations of  $D, r$  and  $f$ , respectively.  $\rho_{Dr}$  and  $\rho_{Df}$  are the correlation coefficients

between  $D$  and  $r$  and  $D$  and  $f$ , respectively.  $\begin{pmatrix} \log M_D - S_D^2/2 \\ \log M_r - S_r^2/2 \\ \log M_f - S_f^2/2 \end{pmatrix}$  is the mean vector, and

$\begin{pmatrix} S_D^2 & \rho_{Dr}S_D S_r & \rho_{Df}S_D S_f \\ \rho_{Dr}S_D S_r & S_r^2 & \rho_{rf}S_r S_f \\ \rho_{Df}S_D S_f & \rho_{rf}S_r S_f & S_f^2 \end{pmatrix}$  is the covariance matrix for  $\begin{pmatrix} \log D \\ \log r \\ \log f \end{pmatrix}$ .

Solving [equation \(1\)](#), we obtain the optimal procurement quantity  $q$ , which can be implicitly expressed as follows. The detailed proofs are shown in [Appendix A](#).

$$\begin{aligned} M_r \Phi \left( \frac{\log q - \log M_D + S_D^2/2 - \rho_{Dr}S_D S_r}{S_D} \right) - M_f \Phi \left( \frac{\log q - \log M_D + S_D^2/2 - \rho_{Df}S_D S_f}{S_D} \right) \\ = M_r - F \end{aligned} \quad (3)$$

where  $\Phi(\cdot)$  is the standard normal distribution function.

Next, we explain the optimal condition [equation \(3\)](#) for the buyer's procurement problem. If the buyer procures too much shipping capacity in the forward market, he will have to sell it in the spot market with the expected price  $M_f$  and obtain the expected net marginal revenue  $M_r - M_f$ . Because the revenue and spot price are uncertain, the expected net marginal revenue should be adjusted by their weights, which are related to the variance of the demand, the correlations between the demand and the spot price, as well as the correlations between the demand and the marginal revenue. The LHS of [equation \(3\)](#) is the buyer's weighted expected marginal overage revenues. On the other hand, if the buyer does not procure enough shipping capacity in the forward market, his expected net marginal revenue is  $M_r - F$ , which is the RHS of [equation \(3\)](#). Therefore, the economic insight of [equation \(3\)](#) is that the buyer's optimal FFA procurement quantity is to equal the weighted expected marginal overage revenues and the expected marginal underage revenues.

Furthermore, if  $\rho_{D_r} S_D S_r \approx \rho_{D_f} S_D S_f$ , i.e.  $\text{cov}(D, r) \approx \text{cov}(D, f)$ , [equation \(3\)](#) can be simplified as:  $\log q = \log M_D - S_D^2/2 + \rho_{D_f} S_D S_f + S_D \Phi^{-1}(z)$  or (4)

$$\log q = \log M_D - S_D^2/2 + \rho_{D_r} S_D S_r + S_D \Phi^{-1}(z) \quad (5)$$

where  $z = \frac{M_r - F}{M_r - M_f}$  and  $\Phi^{-1}(\cdot)$  is the inverse function of the standard normal distribution[3].

From [equation \(4\)](#) and (5), we know that the FFA trading volume ( $q$ ) is related to the expected spot demand ( $M_D$ ), the variance of the spot demand ( $S_D^2$ ), the covariance between the demand and the spot rate ( $\rho_{D_f} S_D S_f$ ) or the covariance between the demand and the earning ( $\rho_{D_r} S_D S_r$ ), as well as the critical ratio ( $z$ ). Exponentiating the both sides of [equations \(4\)](#) or (5), we obtain:

$$q = M_D \exp\left(-S_D^2/2\right) \exp(\rho_{D_f} S_D S_f) \exp[S_D \Phi^{-1}(z)] \quad (6)$$

or

$$q = M_D \exp\left(-S_D^2/2\right) \exp(\rho_{D_r} S_D S_r) \exp[S_D \Phi^{-1}(z)] \quad (7)$$

From [equations \(6\)](#) and (7), we can summarize a buyer's optimal FFA procurement strategy as follows. The optimal FFA procurement quantity is the expected spot demand scaled by the demand covariance term ( $\exp(\rho_{D_f} S_D S_f)$ ) and the demand riskiness term ( $\exp[S_D \Phi^{-1}(z)]$ ) and descaled by the demand volatility term ( $\exp(-S_D^2/2)$ ). The latter three terms consist of a "quantity premium." Investigating the impacts of these determinants to the optimal trading volume, we can obtain the following properties. The detailed proofs are shown in [Appendix A](#):

- A positive relationship exists between the FFA volume and the expected spot demand.
- A positive relationship exists between the FFA volume and the expected earnings.
- A positive relationship exists between the FFA volume and the expected spot rates.
- A negative relationship exists between the FFA volume and FFA prices.
- A positive relationship exists between the FFA volume and the covariance between the spot demand and the spot rates (or the spot demand and the earnings).
- If the volatility of the spot demand is large, there is a negative relationship between the FFA volume and the volatility of the spot demand; otherwise, there is a positive relationship between the FFA volume and the volatility of the spot demand.



From [equations \(4\) or \(5\)](#), we know that the impacts of the spot demand volatility to the FFA trading volume come from two sources: the demand riskiness term  $S_D\Phi^{-1}(z)$ , which has a positive impact, and the demand volatility term  $(-S_D^2/2)$ , which has a negative impact. The higher spot demand volatility can bring the possible higher revenue, but at the same time the possible over-procurement and profit loss. The final impacts depend on their interactions. Note that the demand volatility term is a quadratic function of  $S_D$ , while the demand riskiness term is a linear function of  $S_D$ . Therefore, when the spot demand volatility is large (or small), the demand volatility term dominates (or is dominated by) the demand riskiness term, which causes the negative (or positive) impact to the FFA trading volume finally.

In the next section, we will empirically test these statements.

### 3. Empirical tests

In this section, we use a two-step model specification. The first step is to measure the variance of the spot demand, the covariance between the spot demand and the earnings and the covariance between the spot demand and the spot rates. The DCC-GARCH (multivariate) model is developed to make the estimation. In the second step, the items derived from the DCC-GARCH model are used to analyze the relationship between the FFA trading volume and the various factors by regressions. Finally, our theoretical statements are examined for the three dry bulk shipping markets: Capesize, Panamax and Supramax. Similar two-step estimation procedure can be found in other studies, e.g. [Xu et al. \(2011\)](#).

#### 3.1 Data

The data set in this study consists of weekly FFA prices[4] (FFA), total trading volume (VOL), spot rate indices (SR), fixture demand (FIX) and the earnings (EARNING) for three dry bulk sectors, namely, Capesize, Panamax and Supramax, over the period of July 2009 to February 2016. The FFA prices and trading volume are from the Baltic Exchange. Here, the trading volume series are the total [cleared and over the counter (OTC)] trading activities for all maturity contracts, which are not specific trading activities for first, second, third and fourth nearest quarter FFAs. Weekly FFA prices for first, second, third and fourth nearest quarter (FFA-Q1, FFA-Q2, FFA-Q3, FFA-Q4) are Thursday's prices[5]. We choose these four data series because they are considered as the most liquid contracts in the dry FFA market ([Alizadeh, 2013](#)). The weekly spot rate indices and the earnings are directly from the Clarkson SIN. The fixture demand is used to represent the spot market demand. The fixture information is obtained from both the Clarkson SIN (2013-2016) and the [Baltic Exchange \(2009-2012\)](#). After filtering the missing values and unusable information, a total of 10,687, 16,872 and 10,050 fixture observations are available for Capesize, Panamax and Supramax dry bulk ships, respectively. Based on these data, we obtained the weekly fixture demand by summing the corresponding "Dwt" or "Quantity" for the three bulk ships. The descriptive statistics of these variables are shown in [Table I](#).

From [Table I](#), we find that the FFA trade volume and the spot demand of the Supramax sector is much smaller than the other two sectors. Meanwhile, the standard deviations of these two variables in the Supramax sector are smaller than the other two sectors. These indicate that the Supramax market has low trading activities and liquidity. Moreover, all variables seem to be normally distributed, and the Supramax FFA trade volume and spot demand have higher skewness and kurtosis. Except these two variables, the others seem to be nonstationary according to the PP test for all sectors.

Variable	Mean	Median	Std. dev.	Skewness	Kurtosis	Normality		PP Test	
						Jarque-Bera	p-Val	PP Stat	p-Val
<i>Capesize</i>									
VOL	10,752.000	10,002.000	4,548.472	0.838	3.902	47.401	0.000	-9.820	0.000
FIX	6,523,324.000	5,704,875.000	3,001,588.000	0.856	3.229	39.073	0.000	-3.086	0.029
SR	2,204.716	1,838.100	1,315.736	1.120	4.309	88.064	0.000	-2.669	0.081
EARNING	18,237.300	12,333.340	14,747.610	1.449	5.064	165.623	0.000	-3.774	0.004
FFA-Q1	14,751.02	1,1750.00	9,287.83	1.397	4.235	120.980	0.000	-1.918	0.324
FFA-Q2	15,420.22	13,000.00	8,551.11	1.102	3.355	64.555	0.000	-1.882	0.341
FFA-Q3	15,818.01	13,000.00	8,350.24	1.398	5.217	164.971	0.000	-3.358	0.013
FFA-Q4	19,019.05	15,000.00	8,745.35	0.800	2.602	35.199	0.000	-2.373	0.150
<i>Panamax</i>									
VOL	8,161.975	7,740.000	2,994.957	1.262	5.855	190.554	0.000	-11.435	0.000
FIX	3,821,475.000	3,783,616.000	932,392.800	0.404	3.736	15.699	0.000	-14.630	0.000
SR	1,449.577	1,080.200	926.528	1.310	4.112	106.383	0.000	-2.435	0.133
EARNING	10,045.110	8,334.274	5,740.809	1.425	4.590	139.821	0.000	-2.537	0.108
FFA-Q1	11,091.21	9,175.00	5,739.18	1.233	3.763	86.311	0.000	-1.243	0.657
FFA-Q2	12,332.50	10,625.00	5,825.21	1.322	4.242	110.576	0.000	-1.171	0.688
FFA-Q3	10,857.76	9,200.00	5,318.81	1.319	3.955	102.004	0.000	-1.624	0.469
FFA-Q4	11,920.40	10,400.00	5,447.57	1.060	3.232	58.954	0.000	-1.343	0.610
<i>Supramax</i>									
VOL	2,286.521	2,065.500	1,134.552	1.610	7.492	427.646	0.000	-13.975	0.000
FIX	1,635,444.000	1,618,028.000	686,253.800	0.190	2.263	9.624	0.008	-10.843	0.000
SR	1,211.996	1,011.633	580.352	1.056	3.605	67.545	0.000	-1.582	0.491
EARNING	13,901.770	13,151.980	6,275.077	0.924	3.546	51.985	0.000	-1.347	0.609
FFA-Q1	11,408.15	10,387.50	4,288.96	0.878	3.091	41.478	0.000	-1.082	0.724
FFA-Q2	12,131.75	11,125.00	4,448.66	1.156	4.186	90.599	0.000	-1.111	0.712
FFA-Q3	11,207.03	10,087.50	4,134.54	1.004	3.591	58.835	0.000	-1.286	0.637
FFA-Q4	12,383.51	11,250.00	4,487.99	1.214	4.347	103.477	0.000	-1.765	0.398

**Table I.** Descriptive statistics of FFA prices, trading volume, fixture demand, spot rates and earnings for different dry bulk sectors

**Notes:** The unit of measurement of VOL is lot. The unit of measurement of FIX is ton. The unit of measurement of EARNING is \$/day. The unit of measurement of EARNING is \$/day. Jarque-Bera is the Jarque and Bera test for normality. PP Stat is Phillips and Perron test for unit root

### 3.2 Methodology

**3.2.1 Dynamic conditional correlation–GARCH models.** To test the theoretical statements in Section 2, we need to investigate the time-varying variance of the fixture demand, the time-varying covariance between the fixture demand and the earning and the time-varying covariance between the fixture demand and the spot rate. The DCC-GARCH models, proposed by Engle (2002), are used to characterize the time-dependent conditional covariance of the error terms. These models can detect possible changes in conditional correlations over time, thus allowing for dynamic shocks in response to information. Moreover, the DCC-GARCH model accounts for heteroscedasticity directly by estimating correlation coefficients of the standardized residuals (Tsouknidis, 2016). Therefore, we use the DCC-GARCH(1,1) model in this section.

In our study, the VAR representation is used as the mean equations, which are shown as follows:

$$\ln(ERN_t) = d_1 + \sum_{i=1}^n a_{1i} \ln(ERN_{t-i}) + \sum_{i=1}^n b_{1i} \ln(SR_{t-i}) + \sum_{i=1}^n c_{1i} \ln(FIX_{t-i}) + \varepsilon_{1,t} \quad (8a)$$



$$\ln(SR_t) = d_2 + \sum_{i=1}^n a_{2i} \ln(ERN_{t-i}) + \sum_{i=1}^n b_{2i} \ln(SR_{t-i}) + \sum_{i=1}^n c_{2i} \ln(FIX_{t-i}) + \varepsilon_{2,t} \quad (8b)$$

$$\ln(FIX_t) = d_3 + \sum_{i=1}^n a_{3i} \ln(ERN_{t-i}) + \sum_{i=1}^n b_{3i} \ln(SR_{t-i}) + \sum_{i=1}^n c_{3i} \ln(FIX_{t-i}) + \varepsilon_{3,t} \quad (8c)$$

where  $\varepsilon_{i,t}$  is the error term of the conditional mean equation and the error vector conditional covariance matrix of the vector  $[\ln(ERN_t), \ln(SR_t), \ln(FIX_t)]^T$ . The lag length  $n$  can be determined by the Schwarz information criterion (SC).

The conditional covariance matrix  $H_t$  can be expressed as:

$$H_t = D_t R_t D_t \quad (8d)$$

where  $D_t = \text{diag}(h_{11,t}^{1/2}, h_{22,t}^{1/2}, h_{33,t}^{1/2})$  indicates a diagonal matrix with time-varying standard deviation on the diagonal. Here  $h_{ii,t}$  can be defined as a univariate GARCH(1,1) process:

$$h_{ii,t} = \omega_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{i,t-1}, \forall i = 1, 2, 3 \quad (8e)$$

where  $\alpha_i$  and  $\beta_i$  are non-negative scalars satisfying  $\alpha_i + \beta_i < 1$ . In addition, the conditional correlation matrix  $R_t$  can be specified as:

$$R_t = \text{diag}(q_{11,t}^{-1/2}, q_{22,t}^{-1/2}, q_{33,t}^{-1/2}) Q_t \text{diag}(q_{11,t}^{-1/2}, q_{22,t}^{-1/2}, q_{33,t}^{-1/2}) \quad (8f)$$

where  $Q_t = (1 - \theta_1 - \theta_2) Q^- + \theta_1 z_{t-1} z'_{t-1} + \theta_2 Q_{t-1}$  (8g)

with  $Q^-$  being the unconditional variance matrix of the standardized residuals filtered by the univariate GARCH process (8e) and the non-negative scalar  $\theta_1$  and  $\theta_2$  satisfying  $\theta_1 + \theta_2 < 1$ .

**3.2.2 Linear regression models.** After obtaining the variance of the fixture demand (VARF), the covariance between the fixture demand and the earning (COVFE) and the covariance between the fixture demand and the spot rate (COVFS), we establish the regression models for the three dry bulk shipping markets as follows:

$$\ln(VOL) = A_0 + A_1 \ln(FFA) + A_2 \ln(FIX) + A_3 \ln(ERN) + A_4 \ln(SR) + A_5 \text{COVFS} + A_6 \text{COVFE} + A_7 \text{VARF} + A_8 \text{FV} \quad (9)$$

Here for each sector, the variable  $FFA$  is represented by the weekly average of the FFA daily prices for first, second, third and fourth nearest quarter contracts, i.e. FFA-Q1, FFA-Q2, FFA-Q3 and FFA-Q4, respectively. To investigate the speculation or arbitrage function of FFA and their impacts on the FFA trading volume at the same time, in [equation \(9\)](#), we add the term  $FV$ , which is the volatilities of the returns of FFA. Here, the return of FFA is defined as  $RT_t = \ln(FFA_t) - \ln(FFA_{t-1})$ . According to the method proposed by [Alizadeh \(2013\)](#), we use the GARCH model to calculate  $FV$ . The estimation results of the GARCH model for the Capsize, Panamax and Supramax sector are presented in [Appendix B](#).

By [equation \(9\)](#), we can investigate the relations between the FFA trading volume and the corresponding factors to verify our theoretical statements in Section 2.

3.3 Empirical results

The estimation results of the DCC-GARCH models for the different dry bulk shipping markets are presented in Table II. The estimated time-varying conditional demand variances and correlations generated from the DCC-GARCH model are illustrated in Figures 2-4. Their descriptive statistics are summarized in Table III. From the results, we can observe that the Capesize sector has the larger volatility of its spot demand and stronger covariance

Mean equation	Capesize	Panamax	Supramax
$d_1$	-1.785 <sup>***</sup> (-3.515)	-0.378 (-1.202)	0.218 (1.600)
$d_2$	-0.567 <sup>**</sup> (-2.011)	-0.353 (-1.126)	0.075 (0.719)
$d_3$	8.457 <sup>***</sup> (6.551)	10.400 <sup>***</sup> (5.692)	3.955 <sup>***</sup> (5.971)
$a_1$	0.611 <sup>***</sup> (11.540)	0.839 <sup>***</sup> (25.004)	0.803 <sup>***</sup> (24.392)
$a_2$	-0.179 <sup>***</sup> (-5.852)	-0.105 <sup>***</sup> (-3.469)	-0.075 <sup>***</sup> (-2.897)
$a_3$	0.100 (1.155)	0.017 (0.261)	0.394 <sup>**</sup> (2.822)
$b_1$	0.474 <sup>***</sup> (6.639)	0.117 <sup>***</sup> (4.417)	0.182 <sup>***</sup> (5.681)
$b_2$	1.204 <sup>***</sup> (27.086)	1.065 <sup>***</sup> (43.107)	1.605 <sup>***</sup> (38.483)
$b_3$	-0.241 <sup>**</sup> (-2.270)	0.113 (1.583)	-0.183 <sup>**</sup> (-1.468)
$c_1$	0.123 <sup>***</sup> (4.222)	0.066 <sup>***</sup> (3.195)	0.026 <sup>***</sup> (2.985)
$c_2$	0.047 <sup>***</sup> (2.922)	0.055 <sup>***</sup> (2.678)	0.012 <sup>*</sup> (1.810)
$c_3$	0.512 <sup>***</sup> (6.389)	0.249 <sup>*</sup> (1.894)	0.549 <sup>***</sup> (9.926)
<i>Variance equation</i>			
$\omega_1$	0.000 (0.296)	0.004 (1.648)	0.002 <sup>***</sup> (4.025)
$\alpha_1$	0.011 <sup>***</sup> (57.011)	0.329 <sup>**</sup> (2.202)	0.241 <sup>***</sup> (3.007)
$\beta_1$	0.989 <sup>***</sup> (105.582)	0.335 (1.041)	0.381 <sup>***</sup> (3.322)
$\omega_2$	0.000 (1.478)	0.002 <sup>**</sup> (2.519)	0.001 <sup>***</sup> (2.801)
$\alpha_2$	0.129 <sup>***</sup> (2.930)	0.222 <sup>***</sup> (3.355)	0.615 <sup>**</sup> (5.748)
$\beta_2$	0.850 <sup>***</sup> (16.814)	0.562 <sup>**</sup> (5.113)	0.239 <sup>***</sup> (2.350)
$\omega_3$	0.098 <sup>***</sup> (3.372)	0.045 <sup>**</sup> (7.700)	0.003 (0.760)
$\alpha_3$	0.277 (1.504)	0.325 (1.597)	0.050 <sup>*</sup> (1.737)
$\beta_3$	0.064 (0.482)	0.000 <sup>***</sup> (2.923)	0.928 <sup>***</sup> (17.174)
$\theta_1$	0.031 <sup>***</sup> (67.534)	0.002 (0.100)	0.048 (1.644)
$\theta_2$	0.831 <sup>***</sup> (61.394)	0.980 <sup>***</sup> (75.399)	0.759 <sup>***</sup> (5.370)
<i>Diagnostics</i>			
LogL	278.725	755.850	877.219
AIC	0.434	0.507	0.544
SC	0.427	0.487	0.514
ARCH(12) of ERN	0.253 (0.995)	0.314 (0.987)	0.262 (0.820)
ARCH(12) of SR	0.606 (0.837)	0.384 (0.969)	0.121 (0.998)
ARCH(12) of FLX	0.575 (0.862)	0.976 (0.861)	0.483 (0.924)

**Notes:** \*\*\*, \*\* and \* mean statistically significant at 1%, 5% and 10%, respectively. The t-statistics is reported in the parenthesis. LogL is the log-likelihood. AIC is the Akaike information criterion. SC is the Schwarz information criterion. ARCH(12) is Engle's F-test for ARCH effects. Figures in the brackets under the ARCH(12) estimates indicate the significance levels.

$$\ln(ERN_t) = d_1 + a_1 \ln(ERN_{t-1}) + b_1 \ln(SR_{t-1}) + c_1 \ln(FIX_{t-1}) + \varepsilon_{1,t}$$

$$\ln(SR_t) = d_2 + a_2 \ln(ERN_{t-1}) + b_2 \ln(SR_{t-1}) + c_2 \ln(FIX_{t-1}) + \varepsilon_{2,t}$$

$$\ln(FIX_t) = d_3 + a_3 \ln(ERN_{t-1}) + b_3 \ln(SR_{t-1}) + c_3 \ln(FIX_{t-1}) + \varepsilon_{3,t}$$

$$\varepsilon_t | \Omega_{t-1} \sim (0, H_t), H_t = D_t R_t D_t, D_t = \text{diag} \left( h_{11,t}^{1/2}, h_{22,t}^{1/2}, h_{33,t}^{1/2} \right),$$

$$h_{ii,t} = \omega_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{i,t-1}, \forall i = 1, 2, 3$$

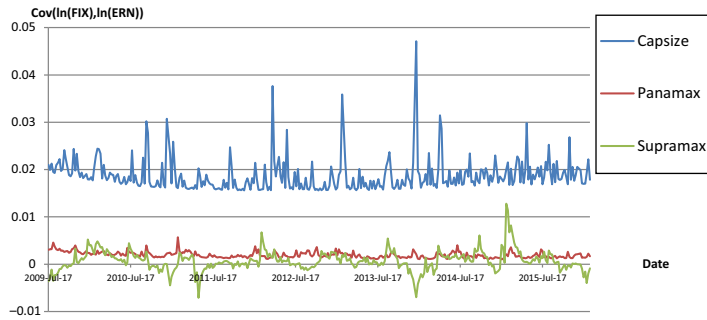
$$R_t = \text{diag} \left( q_{11,t}^{-1/2}, q_{22,t}^{-1/2}, q_{33,t}^{-1/2} \right) Q_t \text{diag} \left( q_{11,t}^{-1/2}, q_{22,t}^{-1/2}, q_{33,t}^{-1/2} \right)$$

$$Q_t = (1 - \theta_1 - \theta_2) \bar{Q} + \theta_1 z_{t-1} z'_{t-1} + \theta_2 Q_{t-1}$$

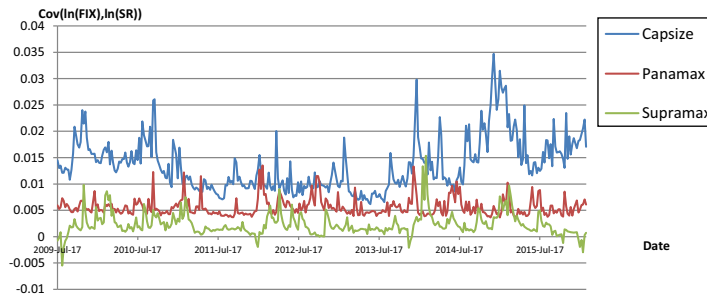
**Table II.**  
The estimates of DCC-GARCH models for different dry bulk sectors

between its spot demand and spot rate (or earning) than the Panamax and Supramax sectors. Meanwhile, the descriptive statistics of the volatilities of the FFA returns for different sectors are summarized in Table III too. It can also be found that the Capesize sector has the larger volatility of the FFA returns than the other two sectors. The larger volatilities of these variables in the Capesize sector can be explained as follows. The main cargoes carried by the Capesize carriers are iron ore and coal, while the Panamax and Supramax carriers can operate more versatile and transport more types of dry bulk cargoes, such as grain, sulfure and fertilizers (Kavussanos *et al.*, 2014). As the world economy is deeply stuck in recession since 2008, the demand for iron ore and coal slumped in recent years. It is easy to understand that the volatility of the spot demand for the Capesize carriers is larger than other carriers. On

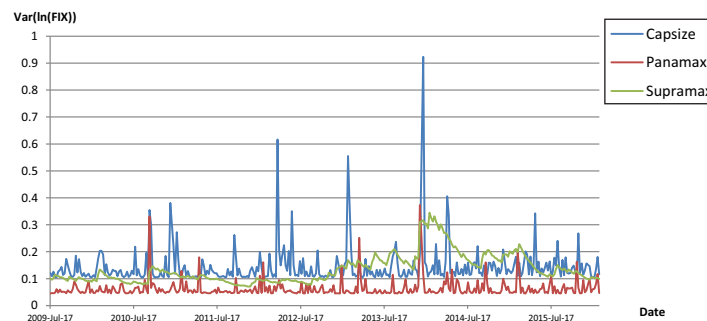
**Figure 2.**  
The dynamic covariance between the fixture demand and the earning for different dry bulk sectors



**Figure 3.**  
The dynamic covariance between the fixture demand and the spot rate for different dry bulk sectors



**Figure 4.**  
The dynamic variance of the fixture demand for different dry bulk sectors



**Table III.** Descriptive statistics of the variance of the fixture demand, the covariance between the fixture demand and the spot rate, the covariance between the fixture demand and the earning and the volatilities of the FFA return for different dry bulk sectors

Variable	Mean	Median	Std. Dev.	Skewness	Kurtosis	Normality		PP Test	
						Jarque-Bera	p-Val	PP Stat	p-Val
<i>Capesize</i>									
COVFEC	0.019	0.018	0.0035	3.247	19.908	4606.23	0.000	-14.0535	0.000
COVFSC	0.014	0.013	0.0062	1.198	4.557	114.57	0.000	-6.092	0.000
VARFC	0.144	0.122	0.072	5.917	52.284	36072.2	0.000	-15.033	0.000
FV-Q1	0.0055	0.0042	0.0038	4.207	30.100	10501.49	0.000	-6.705	0.000
FV-Q2	0.0089	0.0042	0.0171	6.240	50.168	31344.16	0.000	-9.855	0.000
FV-Q3	0.0062	0.0036	0.0112	6.646	53.613	35598.95	0.000	-6.992	0.000
FV-Q4	0.0106	0.0077	0.0179	9.185	90.362	102939.8	0.000	-13.069	0.000
<i>Panamax</i>									
COVFEP	0.00196	0.00179	0.0007	1.37	6.093	239.850	0.000	-10.306	0.000
COVFSP	0.0056	0.0051	0.0017	1.973	7.758	536.497	0.000	-11.679	0.000
VARFP	0.063	0.051	0.033	5.286	40.651	21474.770	0.000	-17.140	0.000
FV-Q1	0.0028	0.0020	0.0026	4.547	33.353	13093.91	0.000	-3.524	0.008
FV-Q2	0.0038	0.0024	0.0055	5.989	47.174	27581.10	0.000	-5.615	0.000
FV-Q3	0.0033	0.0020	0.0051	5.026	33.710	13576.15	0.000	-5.435	0.000
FV-Q4	0.006	0.005	0.0067	11.845	148.212	279615.0	0.000	-10.644	0.000
<i>Supramax</i>									
COVFES	0.0007	0.0005	0.0021	0.909	8.738	508.740	0.000	-7.3116	0.000
COVFSS	0.0023	0.0018	0.0021	1.703	9.907	832.675	0.000	-8.132	0.000
VARFS	0.135	0.116	0.054	1.573	5.482	225.426	0.000	-2.263	0.185
FV-Q1	0.0022	0.0015	0.0029	6.540	55.808	41190.3	0.000	-5.483	0.000
FV-Q2	0.0021	0.0016	0.0017	4.621	28.697	10347.53	0.000	-4.289	0.001
FV-Q3	0.0020	0.0013	0.0033	7.443	66.907	57585.75	0.000	-10.660	0.000
FV-Q4	0.0018	0.0012	0.0024	5.231	32.896	13961.42	0.000	-9.626	0.000

**Note:** Jarque-Bera is the Jarque and Bera test for normality. PP Stat is the Phillips and Perron test for unit root

the other side, the Capesize carriers have more volatile spot rates than other two carriers (Alizadeh and Talley, 2011). Higher volatilities of both spot demand and freight rate mean that the Capesize carriers' demand is more price elastic and they have stronger covariance between their spot demand and spot rates. Meanwhile, the speculation is more active in the Capsize sector (which can be reflected by the larger volatility of the FFA returns) than the other two because of the higher market demand.

The regression results of equation (9) are presented in Table IV, where Q1, Q2, Q3 and Q4 mean the cases that the weekly FFA prices for first, second, third and fourth nearest quarter (FFA-Q1, FFA-Q2, FFA-Q3, FFA-Q4) are used to represent the values of the variable FFA in equation (9), respectively. The columns of Q1, Q2, Q3 and Q4 show the corresponding values of the estimated parameters when the FFA prices in the regression are represented by FFA-Q1, FFA-Q2, FFA-Q3, FFA-Q4, respectively. From Table IV, we can obtain the following observations:

- The spot demand is positively related with the FFA trading volume for all three sectors. This is consistent with our theoretical analysis of Statement (i).
- The spot rate has the positive relation with the FFA trading volume for the Capesize and Supramax sectors. This is consistent with our theoretical analysis of Statement (iii). The reason is obvious that the rising expected spot rate brings more benefits if buyers procure more transport capacity by the FFA trading.

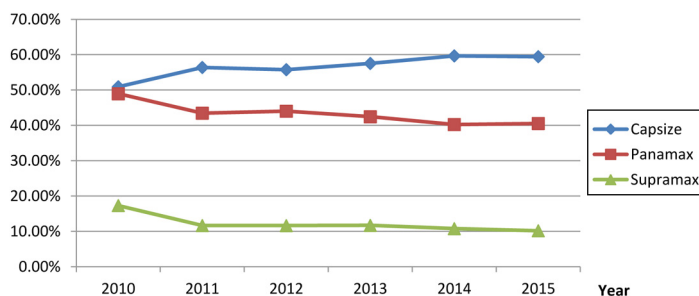
Capesize	Q1	Q2	Q3	Q4
$A_0$	2.457** (2.304)	1.932* (1.910)	0.887 (0.894)	0.977 (1.010)
$A_1$	-0.335*** (-4.392)	-0.266*** (-3.582)	-0.168** (-2.107)	-0.195** (-2.310)
$A_2$	0.387*** (7.187)	0.420*** (8.144)	0.456*** (8.839)	0.468*** (9.266)
$A_4$	0.495*** (7.806)	0.422*** (7.013)	0.366*** (6.024)	0.362*** (6.089)
$A_5$	13.844*** (2.606)	12.739** (2.450)	13.086** (2.244)	12.712** (2.217)
$A_7$	-0.979*** (-2.928)	-0.723** (-2.191)	-0.734** (-2.167)	-0.560* (-1.668)
$A_8$	17.630*** (2.869)	-	-	2.724** (2.260)
<i>Diagnostics</i>				
Adjusted $R^2$	0.326	0.320	0.319	0.298
LogL	-133.199	-137.005	-137.873	-132.71
F Statistics	26.076	29.240	28.713	22.891
AIC	0.898	0.902	0.919	0.901
SC	0.983	0.973	0.991	0.986
DW Statistics	1.520	1.478	1.492	1.550
<i>Panamax</i>				
$A_0$	5.617*** (4.755)	5.159*** (4.157)	5.530*** (4.309)	6.244* (5.199)
$A_2$	0.154* (1.787)	0.135 (1.561)	0.142* (1.618)	0.081 (0.975)
$A_3$	0.089** (2.012)	0.291*** (2.857)	0.263** (2.633)	0.268*** (2.733)
$A_4$	-0.175** (-1.995)	-0.154* (-1.790)	-0.188** (-2.181)	-0.162* (-1.933)
$A_5$	46.654*** (3.081)	61.096*** (4.082)	53.618*** (3.548)	58.729*** (4.059)
$A_7$	-1.864** (-2.492)	-2.119*** (-2.817)	-2.044** (-2.504)	-2.199*** (-3.050)
$A_8$	20.464*** (2.658)	-	13.483*** (3.177)	-
<i>Diagnostics</i>				
Adjusted $R^2$	0.080	0.076	0.108	0.074
LogL	-105.640	-104.826	-100.777	-91.926
F Statistics	6.397	6.228	7.262	4.845
AIC	0.713	0.699	0.691	0.630
SC	0.785	0.770	0.775	0.702
DW Statistics	1.351	1.353	1.373	1.417
<i>Supramax</i>				
$A_0$	3.021*** (2.923)	2.803*** (2.728)	2.696** (2.581)	2.805*** (2.739)
$A_2$	0.181** (2.490)	0.183** (2.508)	0.191*** (2.593)	0.183** (2.513)
$A_4$	0.253*** (3.970)	0.284** (4.660)	0.277*** (4.360)	0.284*** (4.672)
$A_7$	1.642*** (2.687)	1.743*** (2.865)	1.806*** (2.937)	1.742*** (2.860)
$A_8$	16.209* (1.757)	-	15.684* (1.905)	-
<i>Diagnostics</i>				
Adjusted $R^2$	0.109	0.102	0.117	0.111
LogL	-215.643	-217.569	-208.757	-217.721
F Statistics	11.163	13.677	11.623	13.789
AIC	1.325	1.327	1.332	1.324
SC	1.382	1.372	1.391	1.369
DW Statistics	1.658	1.657	1.680	1.658

**Table IV.**  
The estimates of the regression models for different dry bulk sectors

**Notes:** \*\*\*, \*\* and \* mean statistically significant at 1%, 5% and 10%, respectively. The t-statistics is reported in the parenthesis. The variables with insignificant estimates are deleted from the regression equations. LogL is the log-likelihood. AIC is the Akaike information criterion. SC is the Schwarz information criterion. ARCH(12) is Engle's F-test for ARCH effects. Figures in the brackets under the ARCH(12) estimates indicate the significance levels.  $\ln(VOL_t) = A_0 + A_1 \ln(FFA_t) + A_2 \ln(FIX_{t-1}) + A_3 \ln(ERN_t) + A_4 \ln(SR_t) + A_5 COVFS_t + A_6 COVFE_t + A_7 VARF_t + A_8 FV_t$

- The spot demand volatility has the negative relationship with the FFA trading volume for the Capesize and Panamax sectors. For the Capsize sector, this result is consistent with our theoretical statements because the spot demand volatility of the Capsize sector is the highest among the three sectors. The main cargoes carried by the Capsize carriers, e.g., iron ore and coal, have higher demand volatilities[6], which means higher risk for procuring more capacity in the forward market. Therefore, buyers are more cautious about the FFA trading, especially when the volatility of the spot demand is higher. This can restrain the FFA trading volume. One possible explanation for the inconsistency of Statement (vi) in the Supramax sector is its relative lower trading activities (Figure 5). The similar phenomenon and explanations can be found in the relationship between the FFA price change and trading volume in the work of Alizadeh (2013).
- The covariance between the spot demand and the spot rate displays a positive relationship with the FFA trading volume in the Capesize and Panamax sectors. This is consistent with our theoretical analysis of Statement (v). Higher covariance between the spot demand and the spot rate means that buyers have more chances to sell the excess capacity and obtain more revenues in the spot market. This can encourage their trading enthusiasm in the forward market. Because of its lower trading activities, this Statement is not significant for the Supramax sector too.
- FFA prices have a negative impact on the FFA trading volume only for the Capesize sector, which occupies more than 50 per cent of the freight forward market (Figure 5)[7]. This is consistent with our theoretical analysis of Statement (iv).
- In the half of all scenarios, the volatilities of FFA returns have significant and positive impacts on the FFA trading volume, which indicates the speculation or arbitrage exist in most players when they trade FFA. This result is consistent with the literature addressing the speculation or arbitrage activities in FFA trade (Alizadeh, 2013).

In summary, we find that in the Capsize sector, we obtain the most reliable results consistent with our theoretical statements. This is mainly due to its more active trading and better liquidity. The reliable results of the empirical studies in the Capsize sector not only partially verify our theoretical statements, but also supply the traders in the FFA market a possible way to construct their hedging strategies. From equations (6) or (7), we know that a buyer's optimal FFA procurement quantity is the expected spot demand multiplied by the quantity premium, which is determined by the demand covariance term, the demand riskiness term and the demand volatility term. Using the approach proposed by our empirical studies, one can estimate the parameters in equations (6) or (7) and then construct the feasible hedging



**Figure 5.** The FFA trading volume percentages of the Capesize, Panamax and Supramax sectors



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strategy in practice. Moreover, our study indicates the impacts of the spot demand volatility and the covariance between the spot demand and the spot rate to the FFA trading activities. These impacts are not displayed by the other literature and can supply new insights to FFA traders.

#### 4. Conclusions

In this paper, we analyze the determinants on the FFA trading volume from a cross-market perspective. We establish a theoretical model to characterize the determinants and their impacts on the FFA trading volume in the market equilibrium. Then we use a two-step model specification to empirically test our theoretical statements for the Capesize, Panamax and Supramax sectors. The results indicate that the most reliable results consistent with our theoretical statements are presented in the Capsize sector. Our empirical studies can supply the traders in the FFA market a possible way to construct their hedging strategies: the buyer's optimal FFA procurement quantity is the expected spot demand multiplied by the quantity premium, which is determined by the demand covariance term, the demand riskiness term and the demand volatility term. In addition, our study indicates the impacts of the spot demand volatility and the covariance between the spot demand and the spot rate to the FFA trading activities. These impacts can also supply new insights to FFA traders.

Some possible extensions could be considered in future research. One could consider adding some constraints, e.g. the budget constraint, for the procurement in the forward freight market in the theoretical model, and investigate their impacts on the FFA trading volume. This can be implemented by adding a constraint in the buyer's optimization problem. Moreover, cross-market linkages can be reflected from another angle: between forward freight markets and the derivatives markets of the commodities carried by the dry bulk vessels (Kavussanos *et al.*, 2014). Therefore, one can seek other determinants of the FFA trading volume from these derivative markets of the commodities. For instance, the trading volumes and the volatilities of the derivative prices in the derivative markets of the commodities can be included in our model to reveal their impacts on the FFA trading activities.

#### Notes

1. Here, we isolate the hedging impacts of the FFA on its trading volume by our theoretical model. In the empirical studies, we will add the impacts of the speculation or arbitrage of FFA in the regression equations.
2. There are many empirical studies to demonstrate that the shipping demand and freight rate follow the lognormal distributions, e.g. Berg-Andreassen (1997); Kavussanos and Nomikos (1999).
3. In [equation \(4\)](#) and [equation \(5\)](#), it does not matter what base is used in the log function. The base can be the natural base  $e$ , or other bases. In the empirical studies, we use the natural log function.
4. Here, FFA prices are actually BFA (Baltic Forward Assessment) prices from the Baltic Exchange.
5. According to (Alizadeh *et al.* 2015a), Thursday's FFA prices are used to represent the weekly prices to avoid the possible bias due to the weekend effects.
6. We use the sample provided by Stopford (2009, p.422, Table 11.2) to justify this statement. By calculating the coefficients of variation (CVs), which equals to the standard deviation divided by the mean of the maritime transport volumes for different dry bulk cargoes, we know that the CVs of iron ore, coal, grain, agribulks, sugar, fertilizer, Metals and minerals, and steel and forest

products are 0.32, 0.40, 0.17, 0.29, 0.21, 0.08, 0.24 and 0.10, respectively. It can be easily found that the iron ore and coal have higher demand volatilities than other dry bulk cargoes.

- In Figure 5, the FFA trading volume percentage of the Capsize (or Panamax or Supramax) means the percentage of the FFA trading volume of the Capsize (or Panamax or Supramax) sector to the total FFA trading volume.

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### Further reading

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### Corresponding author

Shun Chen can be contacted at: [shunchen@shmtu.edu.cn](mailto:shunchen@shmtu.edu.cn)

**Appendix A. Proof of the theoretical statements**

Here we use the framework proposed by [Secomandi and Kekre \(2014\)](#) to make the proofs. It is obvious that  $\min(q, D) = q - (q - D)^+$ . Therefore, the buyer's profit function can be expressed as follows:

$$\pi = E[rq + (f - r)(q - D)^+ - Fq] \tag{10}$$

Then we can obtain the first order condition as follows:

$$\partial\pi/\partial q = E(r) + E[f \cdot 1(q - D)] - E[r \cdot 1(q - D)] - F = 0 \tag{11}$$

where  $1(\cdot)$  is the indicator function, i.e.:

$$1(q - D) = \begin{cases} q - D & \text{if } q \geq D \\ 0 & \text{if } q < D \end{cases}$$

From the property of multivariate normal distribution, we know that:

$$E(\log r | \log D) = \log M_r - \frac{S_r^2}{2} + \frac{\rho_{Dr} S_D S_r}{S_D^2} \left( \log D - \log M_D + \frac{S_D^2}{2} \right) \tag{12}$$

$$\text{var}(\log r | \log D) = (1 - \rho_{Dr}^2) S_r^2 \tag{13}$$

$$\begin{aligned} E(r|D) &= \exp \left[ E(\log r | \log D) + \frac{1}{2} \text{var}(\log r | \log D) \right] \\ &= M_r \left( \frac{D}{M_D} \right)^{\rho_{Dr} S_r / S_D} \exp \left( \frac{\rho_{Dr} S_D S_r - \rho_{Dr}^2 S_r^2}{2} \right) \end{aligned} \tag{14}$$

Therefore, we have:

$$E[1(q - D)] \cdot E(r|D) = M_r M_D^{-\rho_{Dr} S_r / S_D} \exp \left( \frac{\rho_{Dr} S_D S_r - S_r^2}{2} \right) E[D^{\rho_{Dr} S_r / S_D} \cdot 1(q - D)] \tag{15}$$

From [Secomandi and Kekre \(2014\)](#)'s Lemma 1, we know that:

$$\begin{aligned} E[D^{\rho_{Dr} S_r / S_D} \cdot 1(q - D)] &= \exp \left( \frac{\rho_{Dr}^2 S_r^2 - \rho_{Dr} S_D S_r}{2} \right) M_D^{\rho_{Dr} S_r / S_D} \Phi \\ &\quad \times \left( \frac{\log q - \log M_D + S_D^2 / 2 - \rho_{Dr} S_D S_r}{S_D} \right) \end{aligned} \tag{16}$$

Substituting [equation \(16\)](#) into [equation \(15\)](#), we have

$$E[r \cdot 1(q - D)] = E[1(q - D)] \cdot E(r|D) = M_r \Phi \left( \frac{\log q - \log M_D + S_D^2/2 - \rho_{Dr} S_D S_r}{S_D} \right) \quad (17)$$

Using the same logic, we obtain that:

$$E[f \cdot 1(q - D)] = M_f \Phi \left( \frac{\log q - \log M_D + S_D^2/2 - \rho_{Df} S_D S_f}{S_D} \right) \quad (18)$$

Substituting [equations \(18\)](#) and [\(17\)](#) into [equation \(11\)](#), we can obtain [equation \(3\)](#).

Making the derivations directly based on [equations \(4\)](#) and [\(5\)](#), we can easily obtain:

$$\partial \log q / \partial M_D > 0,$$

$$\partial \log q / \partial M_r > 0,$$

$$\partial \log q / \partial M_f > 0,$$

$$\partial \log q / \partial F < 0,$$

$$\partial \log q / \partial (\rho_{Df} S_D S_f) < 0,$$

$$\partial \log q / \partial (\rho_{Dr} S_D S_r) < 0.$$

Moreover,  $\frac{\partial \log q}{\partial S_D} = \frac{\rho_{Dr} S_D S_r - S_D^2}{S_D}$ . If  $\rho_{Df} S_D S_f > S_D^2$ , i.e.  $Var(D) < cov(D, f)$ ,  $\partial \log q / \partial S_D > 0$ , otherwise,  $\partial \log q / \partial S_D < 0$ .

The same logic can be applied to the case when considering the covariance between the demand and the earning  $cov(D, r)$ .

**Appendix B. The estimates of the GARCH models to calculate the volatilities of the FFA returns**

**Dry bulk FFA trading volume**

Capesize	Q1	Q2	Q3	Q4
$C_0$	-0.00463 (-1.053)	-0.0043 (-1.139)	-0.0037 (-1.004)	-0.010 (-1.556)
$C_1$	0.276*** (3.990)	0.307*** (4.768)	0.327*** (4.857)	0.179** (2.558)
$\omega$	0.0009*** (2.804)	0.0012*** (4.343)	0.0005*** (4.246)	0.0078*** (8.386)
$\alpha$	0.184*** (3.055)	0.654*** (6.086)	0.191*** (3.962)	0.324*** (5.610)
$\beta$	0.668*** (8.004)	0.368*** (5.490)	0.692*** (14.650)	-0.062 (-0.561)
<i>Diagnostics</i>				
Adjusted $R^2$	0.061	0.026	0.014	-0.038
Log-likelihood	389.53	378.10	406.262	296.04
DW Statistics	2.014	2.127	2.210	2.332
AIC	-2.457	-2.361	-2.572	-1.878
SC	-2.397	-2.302	-2.512	-1.817
ARCH(12)	0.512 (0.907)	0.499 (0.915)	0.409 (0.960)	0.072 (1.000)
<i>Panamax</i>				
$C_0$	-0.0034 (-1.371)	-0.0031 (-1.006)	-0.0043 (-1.777)	0.003 (0.518)
$C_1$	0.185*** (3.356)	0.102 (1.593)	0.230*** (3.742)	0.044 (0.465)
$\omega$	0.0002** (2.081)	0.0001* (1.885)	0.0001** (2.516)	0.005*** (14.225)
$\alpha$	0.243*** (3.716)	0.209*** (5.027)	0.201*** (4.257)	0.177** (2.784)
$\beta$	0.701*** (8.619)	0.806*** (27.55)	0.751*** (16.681)	-0.059 (-1.434)
<i>Diagnostics</i>				
Adjusted $R^2$	0.030	0.010	0.006	-0.032
Log-likelihood	512.508	485.79	511.05	401.53
DW Statistics	1.986	1.982	2.151	2.472
AIC	-3.243	-3.043	-3.244	-2.558
SC	-3.183	-2.984	-3.184	-2.498
ARCH(12)	1.572 (0.099)	0.221 (0.997)	0.266 (0.994)	1.099 (0.361)
<i>Supramax</i>				
$C_0$	-0.0034 (-1.507)	-0.0051** (-2.186)	-0.004** (-1.916)	-0.003 (-1.625)
$C_1$	0.187*** (2.974)	0.087 (1.206)	0.214*** (3.252)	0.189 (26.440)
$\omega$	0.000*** (3.175)	0.000*** (2.703)	0.0002*** (3.03)	0.000 (5.433)
$\alpha$	0.193*** (4.212)	0.080*** (3.904)	0.210*** (3.434)	-0.039 (-9.863)
$\beta$	0.787*** (20.13)	0.891*** (37.543)	0.639*** (7.358)	1.013 (124.376)
<i>Diagnostics</i>				
Adjusted $R^2$	0.014	-0.0068	0.017	-0.009
Log-likelihood	598.51	579.43	591.43	628.91
DW Statistics	2.050	2.092	1.89	2.141
AIC	-3.554	-3.450	-3.654	-3.736
SC	-3.497	-3.393	-3.595	-3.679
ARCH(12)	1.198 (0.284)	0.068 (1.000)	1.187 (0.291)	1.594 (0.092)

Notes: \*\*\*, \*\*, and \* mean statistically significant at 1%, 5% and 10%, respectively. The t-statistics is reported in the parenthesis. LogL is the log-likelihood. AIC is the Akaike information criterion. SC is the Schwarz criterion. DW statistics is the Durbin-Watson statistics. ARCH(12) is Engle's F-test for ARCH effects. Figures in the brackets under the ARCH(12) estimates indicate the significance levels.  $RT_t = C_0 + C_1 \cdot RT_{t-1} + \varepsilon_t$ ,  $\varepsilon_t \sim (0, h_t)$ ,  $h_t = \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1}$

**Table AI.**  
The estimates of the GARCH models to calculate the volatilities of the FFA returns for different dry bulk sectors