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The dynamics between freight volatility and fleet size growth in dry bulk shipping markets

Jane Jing Xu^{a,*} Tsz Leung Yip^b, and Peter B. Marlow^a

^a Logistics and Operations Management Section, Cardiff Business School, Cardiff University, Cardiff CF10 3EU, UK

^b Department of Logistics and Maritime Studies, Faculty of Business, The Hong Kong Polytechnic University, Hung Hom, Hong Kong

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Abstract

This paper studies the relationship between the time-varying volatility of dry bulk freight rates and the change of the supply of fleet trading in dry bulk markets. An abundance of research has been done to understand the time-varying characteristics of freight rate volatility, yet few have discussed the determinants of freight volatility. We therefore examine freight volatility against the changes in fleet size and other shipping market variables over January 1973 to October 2010. The study employs a two-step model specification. The first step is the measurement of freight rate volatility through an AR-GARCH model; the second step is the analysis of the relationship between freight rate volatility and fleet size growth through a GMM regression. We confirm similar findings in the literature that freight rate volatility is time varying. Furthermore, the results reveal that the change in fleet size positively affects freight rate volatility, while the spot rate volatility of Capesize dry bulk exhibits a stronger reaction to the change in fleet size. The

* Corresponding author. Tel.: +44 029 2087 6851; Fax: +44 029 2087 4301.
E-mail address: xujj1@cardiff.ac.uk.

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results of this study contribute in a general sense to understanding the systematic risk of shipping markets.

Key words: Freight markets; Freight volatility; Fleet size; GARCH

Highlights:

We examine the determinants of freight volatility in dry bulk shipping markets.

We adopt a two-step model specification: a GARCH model and a GMM regression.

Fleet size growth has a positive impact on freight volatility.

Freight rate volatility is time varying.

1. Introduction

Freight volatility denotes the variability or the dispersion of the freight rate. The larger the freight volatility is, the more the freight rate fluctuates. Previous studies show that freight volatility can be forecasted but based largely on its past values. An abundance of studies have been carried out in an attempt to understand the time-varying characteristics of freight rate volatility (Kavussanos, 1996a and 1996b; Kavussanos, 2003; Lu, Marlow and Wang, 2008; among others), yet among them only a few have discussed what are the causes and impacts of the time-varying risk in shipping markets. For example, Adland and Cullinane (2006) modeled volatility as a function of the level of freight rate themselves. Kavussanos and Visvikis (2004) and Batchelor, Alizadeh and Visvikis (2005) studied shipping risk by analyzing the impact of the volatility of shipping derivatives. We are left with the question of what causes this time-varying freight volatility.

In financial risk management, the CAPM (Capital Asset Pricing Model) has been widely accepted as high risk denoting high return, and most research has attempted to determine the risk level of individual companies. However, the systematic (or market) risk is not well determined. There are few markets like shipping with such characteristics as the supply capacity being well defined and the size of supply inelastic to market rate. In other markets, it may be difficult to measure the capacity of supply or the supply is not fixed. Our study aims to find the relationship between the time-varying volatility of dry bulk freight rates and the change of the supply of fleet trading in the dry bulk shipping markets, namely fleet size.

Imagine a market for any goods where initially there is only one buyer and one seller. Later more buyers and more sellers with more capital join the trade, one seller has more goods to sell or one buyer has more capital to buy. This may increase the uncertainty in the market. This scenario could be extended to the shipping market: During normal market conditions with slow and predictable trade volume growth, the change in fleet supply will also reflect such stable growth conditions and the freight market will be near an equilibrium with correspondingly low and less volatile freight rate (as in the pre-2003 dry bulk market). If there is a sudden positive change in demand growth (e.g. the emergence of China as a major importer in the post-2003 period), then there will first be a boom in freight rates and therefore freight volatility and ultimately increasing supply growth (scrapping would cease immediately and increased newbuilding would commence). The increased uncertainty with regards to what future fleet requirements

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will be, and the inherent risk of overtonnaging, will lead to greater volatility for a prolonged time period (as observed in the 2003 - 2010 market). We therefore postulate our a priori hypothesis: in dry bulk shipping markets, an increase in the change of the size of fleet trading in the market leads to an increase in freight rate volatility.

In general, previous studies of freight markets focus on the modeling of freight rates assuming the market remains static (see, for example, Beenstock and Vergottis, 1993), or on estimating the freight rate volatility of individual markets (see, for example, Kavussanos, 1996a and 1996b). We study the dynamics between the time-varying freight rate volatility and the change of fleet market capacity. The aim of this empirical study is to determine the impact of the change in fleet size on the market risk in shipping.

The remainder of this paper is organized as follows. Section two reviews the related literature. Section three discusses the research methodology. Section four describes the data properties and the empirical results. Section five summarizes the findings.

2. Literature Review

Freight risk has been a core subject in maritime studies because shipping markets have generated alternative investment opportunities attracting the interest of investor groups in the last decade. Ever since the classical works of Tinbergen (1931 and 1934) and later Zannetos (1966), what we have known in maritime economics is the hockey-stick shape of the supply function in shipping along with inelastic demand function that generates time-varying volatility. By definition a highly overtonnaged market will lack volatility

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while a freight market near capacity will exhibit very large volatility. We do not yet know well how to model this volatility from a fundamental point of view, apart from as function of the freight rate itself as in Adland and Cullinane (2006) or in the various time series analysis models as in Kavussanos (1996a and 2003). This paper is therefore an attempt at expanding our understanding of such fundamental market models of freight market volatility.

Kavussanos (1996a) applied the ARCH model to shipping markets for the first time. He extended the model to investigate volatility of the spot and time-charter rates in the dry bulk shipping markets. He found that risks in both freight and time-charter dry bulk markets are time-varying and risk is generally higher in the time-charter market than the spot market and higher for larger ships than smaller ones. Kavussanos (1996b) also applied ARCH model to estimate the price volatility of tanker market. Kavussanos (2003) further employed the GARCH model to examine the risks in the tanker freight market and found that the risks in the tanker market vary over time. Time-charter rates have lower volatility than spot rates, while the freight rate of larger vessels has higher volatility than that of smaller ones. Lu, Marlow and Wang (2008) investigated the characteristics of freight rate volatility in three different types of bulk vessel using recent data from March 1999 to December 2005. Applying the GARCH model, they verified the time-varying behavior of dry bulk freight rates and found that market shocks have different magnitudes of influence on volatility in different vessel sizes and different time periods. From this perspective, the time-varying behavior of freight rates has been verified in a wide range of shipping studies. Besides the freight rates, an abundance of empirical work

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on shipping markets has also applied this methodology to model second-hand ship prices (Kavussanos, 1997), risk premium in freight markets (Kavussanos and Alizadeh, 2002b; Adland and Cullinane, 2005), and freight futures markets (Kavussanos and Visvikis, 2004; Kavussanos, Visvikis and Batchelor, 2004; Batchelor, Alizadeh and Visvikis, 2005); all these shipping related time series are shown to exhibit time-varying volatilities.

Despite this abundant research into the time-varying characteristics of shipping risks, there has been little done on the relationship between the price volatility and other variables. In other words, what impacts price volatility and what causes this time-varying risk in shipping. The exceptions are studies by Kavussanos and Visvikis (2004), Batchelor, Alizadeh and Visvikis (2005) and Alizadeh and Nomikos (2011). Kavussanos and Visvikis (2004) discussed market interactions in returns and volatilities between spot and forward shipping freight markets. Batchelor, Alizadeh and Visvikis (2005) examined the relationship between Forward Freight Agreement (FFA) price volatility and bid-ask spread (BAS). They first applied AR-GARCH(1,1) model to estimate the FFA volatility, then used General Methods of Moments (GMM) to examine the relationship between FFA volatility and BAS. The results indicate a positive relationship between FFA volatility and BAS on certain routes, which shows that risk is a stable determinant of future direction of FFA market. Alizadeh and Nomikos (2011) applied EGARCH models and found that the volatility of freight rate is related to the term structure of the freight market. We do not know well how to model freight volatility from a fundamental point of view. In this paper we aim to determine the relationship between the time-varying volatility of freight rates and the change of fleet size, among other variables.

3. Methodology

Stopford (1997) described the basic shipping supply and demand functions as shown in Figure 1. The fleet supply function (S) is a hockey stick shaped curve, it works by moving ships in and out of service in response to freight rate. The ship supply function is elastic when freight rate is low and inelastic when freight rate is high. The fleet demand function (D) is almost vertical, and it shows how charterers adjust to changes in freight rate. Due to the lack of alternative transport mode, shippers ship the cargo regardless of the cost.

| Figure 1 |

Most previous studies which model the freight market (see, for example, Beenstock and Vergottis, 1993; Kavussanos, 1996a; Kavussanos, 2003) have also concentrated on explaining the determinants of freight rate (*FR*) from the perspective of shipping supply and demand. The following three variables including fleet supply and demand have been widely used:

$$\text{Freight rate} = f(\text{Fleet size}, \text{Industrial production}, \text{Bunker price}) \quad (1)$$

where fleet size (*FS*) indicates the supply of fleet trading in shipping market, industrial production (*IP*) denotes the demand for shipping services, and bunker price (*BP*) reflects the transportation costs. According to previous empirical results, *IP* and *BP* are found to

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positively affect FR , while FS has a negative effect on FR . There have been abundant studies analyzing the determinants of freight rate.

We attempt to determine the impact of the change in fleet size on the freight rate volatility. To analyze the relationship between them, the freight rate volatilities are regressed against variables that represent the changes of the supply of fleet, the demand for shipping services, and the transportation costs.

$$h_t = c_0 + c_1 \ln FS_t + c_2 \ln FS_t^2 + c_3 \ln FR_t + c_4 \ln IP_t + c_5 \ln BP_t + u_t \quad (2)$$

where the freight rate volatility in logarithm (h_t) is defined as the one-step ahead conditional volatility of freight rate from an AR-GARCH model, the change in fleet size is evaluated by $\ln FS_t$ and $\ln FS_t^2$, the change in freight level by $\ln FR_t$, the change in demand for shipping services by $\ln IP_t$, and the change in transportation costs by $\ln BP_t$. The second order term of fleet size is included in the regression according to Ramsey's RESET Test, which is a general test for mis-specification that may manifest itself in terms of missing variables and/or incorrect functional form. It should be noticed that Equation (2) is in the log-log specification and the estimated coefficients measure the change in volatility per unit change in explaining variables, therefore the variables can be thought of as small changes in themselves (Wooldridge, 2009).

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This study employs a two-step model specification. The first step is the measurement of freight rate volatility. The price volatility has been measured in two ways in related literatures.

(1) The volatility is assumed to be stationary, measured by standard deviations of different samples or observations (see, for example: Hnatkovska and Loayza, 2004; Rose, 2006; Furceri and Karras, 2007).

(2) Alternatively, the volatility is non-stationary, measured by continuous time-changing variances of the same sample (see, for example: Kavussanos, 1996a & 2003; Adland and Cullinane, 2005; Lu, Marlow and Wang, 2008). The latter approach is used in this paper to verify the time-varying characteristics of shipping risks.

The approach to determine the dynamic volatility is associated with the following remarks. The Autoregressive Conditional Heteroskedasticity (ARCH) and Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models are employed commonly in modeling volatility of financial time series that exhibit time-varying volatility clustering, that is, periods of swings followed by periods of relative calm. The ARCH model was introduced by Engle (1982) to model the volatility of UK inflation. Since then this methodology has been employed to capture the empirical regularity of non-constant variances, such as stock return data, interest rates and foreign exchange rates (Bollerslev and Melvin, 1994, among others). However, this methodology, despite its abundance of results elsewhere, had not been applied before in shipping markets until Kavussanos (1996a) for the first time implemented ARCH and GARCH models to analyze the time-varying behavior in freight rates. The time-varying characteristic of the

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volatility has been found to exist among most shipping related time series, for example, bulk shipping freight rate (Kavussanos, 1996a; Adland and Cullinane, 2005), second-hand ship price (Kavussanos, 1997), forward freight agreement (FFA) price (Batchelor, Alizadeh and Visvikis, 2005). The GARCH model has been widely used to examine the time-varying volatilities of shipping related time series. The ARCH model considers the variance of the current error term to be a function of the variances of the previous time period's error terms. ARCH relates the error variance to the square of a previous period's error. As the name suggests, the model has the following properties:

- (1) Autoregression - Uses previous estimates of volatility to calculate subsequent (future) values. Hence volatility values are closely related.
- (2) Heteroskedasticity - The probability distributions of the volatility varies with the current value.

In this paper, we apply AR-GARCH (p, q) to model the conditional volatility of freight rate, since it has been proved that a GARCH model adequately fits many economic time-series (Bollerslev, 1987).

$$r_t = b_0 + b_1 r_{t-1} + b_2 r_{t-2} + \dots + b_m r_{t-m} + \varepsilon_t, \quad \varepsilon_t \sim iid(0, h_t) \quad (3)$$

$$h_t = \omega + \sum_{i=1}^q \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^p \beta_i h_{t-i} \quad (4)$$

where r_t is the natural logarithm of the monthly freight rate change evaluated by first difference of monthly freight rate $r_t = \Delta FR_t$. h_t is the conditional variance. ε_t is the error term that follows a normal distribution with mean zero and time-varying variance h_t . p is the order of the GARCH terms h_t and q is the order of the ARCH terms ε_t^2 .

Using the freight rate volatility (h_t) derived from AR-GARCH model to represent freight market risk, we then analyze the relationship between freight market risk and the change of fleet size. h_t is regressed against the change in fleet size by $\ln FS_t$ and $\ln FS_t^2$, the change in freight level by $\ln FR_t$, the change in demand for shipping services by $\ln IP_t$, and the change in transportation costs by $\ln BP_t$, as shown in Eq. (2). We first employed Ordinary Least Squares (OLS) to test the result. However, OLS or Generalized Least Squares (GLS) often lead to inconsistent estimation. The coefficient value or significant level may be seriously upward biased due to failures of some assumptions, such as collinearity, autocorrelation, and heteroscedasticity, which imply inefficient standard errors.

Thus, we consider estimating the model using the generalized method of moments (GMM) approach. GMM is a very general statistical method for obtaining estimates of parameters of statistical models. In the twenty years since it was first introduced by Hansen (1982) of the method of moments, GMM has become a very popular tool among empirical researchers. It is also a very useful heuristic tool. Many standard estimators, including instrument variable (IV) and ordinary least squares (OLS), can be seen as special cases of GMM estimators.

GMM is a good estimator for dealing with autocorrelation and heterogeneity issues. The GMM approach allows an instrument to be used, thereby avoiding any simultaneity bias. It also brings the advantage of consistent estimation in the presence of heteroscedasticity

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and autocorrelation (Newey and West, 1987). Baum et al. (2003) also mentioned that GMM makes use of the orthogonality conditions to allow for efficient estimation in the presence of heteroskedasticity of unknown form.

4 Data Description and Empirical Results

4.1 Data Description

In the analysis, the data sets consist of monthly freight rate, fleet size (*FS*), industrial production (*IP*) and bunker price (*BP*). The freight rate is specified into Panamax and Capesize spot rate (*SPR*) and one-year time-charter rate (*TCR*) in the dry bulk shipping industry while the fleet size is also divided into Panamax and Capesize bulk carriers (*FS_p*, *FS_c*) as two types of dry bulk supply. The samples for Panamax spot rate (*SPR_p*) and Capesize spot rate (*SPR_c*) cover the period from January 1973 to October 2010, the sample for Panamax time-charter rate (*TCR_p*) covers the period from January 1976 to October 2010 and Capesize time-charter rate (*TCR_c*) from January 1977 to October 2010. All freight rates, fleet size and bunker price data are collected from Clarkson Research Services Ltd., while the industrial production indices are from OECD Statistics. The time series are transformed into natural logarithmic form.

Descriptive statistics of logarithmic freight rates and fleet size are presented in Table 1. The *J-B* statistic rejects the hypotheses of normality for freight rates and fleet size in both ship types. The Ljung-Box Q-statistics are for auto-correlation test and the test results indicate that the *p*-value of the first 12 lags of the raw series and of the squared series is 0, which demonstrates significant auto-correlation. The Augmented Dickey-Fuller (ADF)

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unit root test on the monthly log first-difference freight rate and fleet size series is applied to examine whether the series are stationary. The results indicate that for both ship types the log first-difference of freight rate and fleet size series are stationary.

| Table 1 |

4.2 Empirical Results

To analyze the relationship between freight market risk and the change in fleet size, one-step ahead conditional volatility estimates (h_t) of freight rates are constructed through the AR-GARCH model. We first choose the best auto-regression (AR) model for the four freight rate series (SPR_p , TCR_p , SPR_c and TCR_c), determined by Schwartz Information Criterion (SIC). Results show that AR(1) is the most suitable lag for the four series. We also apply ARCH LM test (Engle, 1982) to check the autocorrelated conditional heteroskedasticity in the residuals of the AR models. The results show the presence of ARCH effects in freight volatility. We then use the AR-GARCH (p, q) model to estimate the freight rate volatility. AR-GARCH (1, 1) is selected to be the appropriate specification. GARCH (1, 1) has been shown to be a generous representation of conditional variance that adequately fits many economic time series (Lu, Marlow and Wang, 2008). The empirical results are reported in Table 2. For all four freight rate series, the coefficients of the lagged variance (β) and the lagged squared error (α) terms are significant at 5% critical levels. Bollerslev (1987) mentioned that the persistence in variance is measured by the sum ($\alpha + \beta$). In our analysis, the results show that $(\alpha + \beta) > 1$, which indicates that the GARCH process is non-stationary. We therefore

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confirm similar findings in the literature (Kavussanos, 1996a; Kavussanos, 2003; Adland and Cullinane, 2005; Lu, Marlow and Wang, 2008) that the volatility of both spot rate and time-charter rate in dry bulk markets are time-varying.

| Table 2 |

The estimated conditional volatilities for SPR_p , TCR_p , SPR_c and TCR_c are presented in Figures 2 to 5. The figures show time-varying volatility clustering: large changes in volatilities occur around certain periods of time, and then small changes in volatility follow, which indicates that volatility tends to stay high during and after periods of large external shocks to the industry. ARCH and GARCH models are employed commonly in modeling volatility of time series exhibiting this characteristic.

| Figures 2-5 |

With the time-varying freight rate volatilities (h_t) derived from the AR-GARCH models, we analyze the relationship between freight market risk and the change in fleet size. The freight rate volatilities (h_t) are then regressed against the changes in fleet size, freight rate, industrial production and bunker price as in Eq. (2). All the variables are transformed into natural logarithmic form.

| Table 3 |

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The results of the GMM regressions are presented in Table 3. The goodness of fit is reasonable with the adjusted *R*-squared values of 0.736 to 0.773. The adjusted *R*-squared values of the freight rate volatility regression are considerably high compared to other studies on price volatility (e.g. Devereux and Lane's (2003) study on exchange rate volatility). The Ljung-Box *Q*-statistics indicate the existence of serial correlation in all regressions, which justifies the use of GMM as a good estimator to deal with autocorrelation and heterogeneity issues.

Both the coefficients showing the change in Fleet Size ($\ln FS$ and $\ln FS^2$) are significant at the 1% level (except for Panamax Spot), with $\ln FS$ negatively related to h_t , and $\ln FS^2$ positively related to h_t . This can be interpreted as there being a declining linear effect and an increasing non-linear effect of the change in fleet size on the freight volatility. With the increase in the value of $\ln FS$, the non-linear term will take dominant effect over the linear term, which suggests that the increase in the change of the size of the fleet trading in the market leads to an increase in freight rate volatility. The linear and non-linear effects together suggest that the large volatility change is a result of non-linear effect of the change in fleet size. The spot rate volatility of Capesize dry bulk exhibits a stronger reaction to the change in fleet size than Panamax dry bulk, which can be explained since Capesize ships are more vulnerable to market changes due to the trading inflexibility of larger vessels.

Previous research considered the modeling of: $FR=f(FS, IP, BP)$ (see, for example, Kavussanos, 1996a), with coefficients: $(FS-, IP+, BP+)$. Our research considers the

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relationship of the volatility h_t and $(\ln FS_t, \ln FS_t^2, \ln FR_t, \ln IP_t$ and $\ln BP_t)$ with coefficients $(\ln FS_{t-}, \ln FS_{t+}^2, \ln FR_{t+}, \ln IP_{t-}$ and $\ln BP_{t+})$. We have discussed that there is a declining linear effect and an increasing non-linear effect of the change in fleet size on freight volatility. With respect to the other variables, the change in freight rate exhibits a positive impact on freight volatility, which indicates that the freight market is riskier given a higher freight rates growth. It is observed that the variables industrial production growth and bunker price growth are statistically less contributive to freight volatility, so there might be a possibility of spurious results concerning these two variables. The change in industrial production is negatively related to freight volatility, it can be explained that a higher demand growth helps soothe the tense situation of freight market; the change in bunker price is positively related to freight volatility (Capesize Time Charter), possible explanation is that transport costs are passed partially on freight rate, thus bunker price growth positively affects freight volatility (but only in low freight markets where the marginal cost argument holds). As shown in Figures 2-5, the freight volatility exhibits a one-off jump in the pre- and post-2004 periods. We therefore shorten the observation period from January 1973 to December 2004 and replicate the preceding analysis for a robustness check. The sensitivity results (can be requested from the author) are in consistence with the earlier analysis. There is no clear evidence that the market condition and time periods have substantially changed the positive impact of fleet size growth on freight volatility.

5. Conclusion and Further Research

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This study provides valuable insights into the current status of freight risk management in the literature. This study provides statistically significant evidence that fleet size growth is a critical determinant of freight volatility and affects it in a nonlinear manner.

This paper postulates an a priori hypothesis that, in dry bulk shipping markets, an increase in the change of the supply of fleet trading in the market leads to an increase in freight rate volatility. We employ a two-step modeling to examine the relationship between freight market risk and fleet size. We confirm through the AR-GARCH model the similar findings in the literature that the volatilities of both spot rate and time-charter rate in dry bulk markets are time varying, and the freight rate volatility series exhibit clustering characteristics, indicating that volatility tends to stay high during and after periods of large external shocks to the industry. Through the GMM regression, we validate our a priori expectation that the change in fleet size positively affects freight rate volatility. The spot rate volatility of Capesize dry bulk exhibits a stronger reaction to the change in fleet size as Capesize ships are more vulnerable to market changes due to the trading inflexibility of larger vessels.

This study contributes in a general sense to understanding the systematic risk of shipping markets. Given the positive effect of the change in fleet size on freight rate volatility, ship investors should be wary of the market supply in the dry bulk shipping sector. Further research is needed to compare systematic risks across different markets and to explore their size effects.

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Table 1
Descriptive statistics of logarithmic first difference freight rates and fleet size

	<i>N</i>	<i>Mean</i>	<i>Median</i>	<i>S.D.</i>	<i>Skewness</i>	<i>Kurtosis</i>	<i>J-B</i>	<i>Q(12)</i>	<i>Q²(12)</i>	<i>ADF(lags)</i>
Panel A: Panamax bulker series (January 1973 to October 2010)										
SPR_p	405	2.089	1.978	0.539	0.945	3.639	67.188	33.407	36.804	-16.814 (0)
TCR_p	417	9.150	9.180	0.601	0.719	4.409	70.402	96.407	111.000	-12.448 (1)
FS_p	454	3.779	3.802	0.643	-0.441	2.502	19.435	726.110	801.220	-4.911 (3)
Panel B: Capesize bulker series (January 1973 to October 2010)										
SPR_c	453	2.377	2.303	0.674	0.801	3.712	58.037	98.594	104.810	-15.137 (1)
TCR_c	377	9.292	9.337	0.616	0.334	3.118	7.212	57.250	65.063	-13.431 (0)
FS_c	454	3.845	4.007	0.795	-0.441	2.229	25.966	281.150	282.570	-5.407 (2)

Note:

- *N* is the number of observations.
- *S.D.* is the standard deviation of the series.
- *J-B* is the Jaeque-Bera test for normality, distributed as $\chi^2(2)$.
- *Q(12)* and *Q²(12)* are the Ljung-Box Q statistics of the raw series and of the squared series, distributed as $\chi^2(12)$ under the null hypothesis of nonserial correlation with lags up to 12.
- *ADF* is the Augmented Dickey-Filler test; the appropriate lag lengths (in parentheses) are based on Schwartz Information Criterion (SIC); the 5% critical value is -2.868.
- *SPR*, spot rate; *TCR*, time-charter rate; *FS*, fleet size
- Subscript: *p*, Panamax; *c*, Capesize

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Table 2

AR-GARCH model estimates of the SPR_p, TCR_p, SPR_c and TCR_c conditional volatilities

$$r_t = b_0 + b_1 r_{t-1} + b_2 r_{t-2} + \dots + b_m r_{t-m} + \varepsilon_t; \varepsilon_t \sim iid(0, h_t)$$

$$h_t = \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1}$$

	<i>SPR_p</i> (January 1973- October 2010)	<i>TCR_p</i> (January 1976- October 2010)	<i>SPR_c</i> (January 1973- October 2010)	<i>TCR_c</i> (January 1977- October 2010)
<i>b₁</i>	0.209**	0.444**	0.332**	0.461**
Std. Error	0.061	0.066	0.053	0.064
z-Statistic	3.431	6.750	6.213	7.219
Prob.	0.001	0.000	0.000	0.000
<i>ω</i>	0.033**	22632.770**	0.029**	17679.480**
Std. Error	0.011	9413.621	0.009	9714.712
z-Statistic	2.952	2.404	3.078	1.820
Prob.	0.003	0.016	0.002	0.069
<i>α</i>	0.233**	0.344**	0.354**	0.251**
Std. Error	0.053	0.046	0.036	0.025
z-Statistic	4.392	7.463	9.960	9.859
Prob.	0.000	0.000	0.000	0.000
<i>β</i>	0.785**	0.735**	0.711**	0.815**
Std. Error	0.046	0.033	0.037	0.024
z-Statistic	17.044	22.594	19.457	34.486
Prob.	0.000	0.000	0.000	0.000
<i>α + β</i>	1.018	1.079	1.065	1.067

Note:

- **(*) denotes significance at 10% (5%) critical value levels.
- SPR, spot rate; TCR, time-charter rate

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Table 3

GMM estimates of the relationship between freight rate volatility and fleet size growth

$$h_t = c_0 + c_1 \ln FS_t + c_2 \ln FS_t^2 + c_3 \ln FR_t + c_4 \ln IP_t + c_5 \ln BP_t + u_t$$

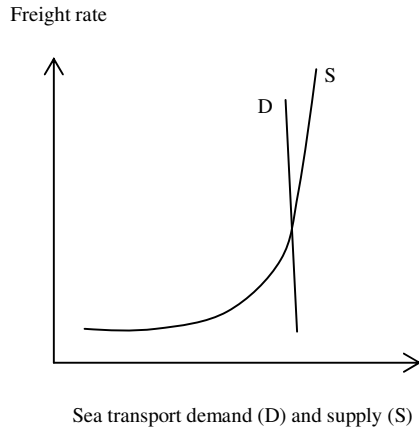
<i>Explanatory variables</i>	<i>Panamax Spot (January 1973- October 2010)</i>	<i>Panamax Time Charter (January 1976- October 2010)</i>	<i>Capesize Spot (January 1973- October 2010)</i>	<i>Capesize Time Charter (January 1977- October 2010)</i>
c_0	8.142 (1.289)	44.598** (4.611)	14.526** (2.817)	28.382** (3.285)
$\ln FS_t$	0.646 (0.254)	-13.766** (-5.935)	-6.300** (-5.427)	-6.157** (-3.715)
$\ln FS_t^2$	0.056 (0.167)	2.132** (5.924)	0.946** (5.848)	1.105** (4.112)
$\ln FR_t$	2.093** (9.808)	1.648** (7.823)	1.963** (9.233)	0.789** (4.541)
$\ln IP_t$	-3.621** (-3.491)	-5.522** (-2.934)	-1.894 (-1.430)	-4.329* (-2.288)
$\ln BP_t$	-0.023 (-0.114)	-0.256 (-1.057)	-0.232 (-1.159)	0.724** (3.253)
R^2	0.736	0.736	0.773	0.768
Adj. R^2	0.732	0.733	0.770	0.765
Q(12)	743.210 [0.000]	901.840 [0.000]	1006.900 [0.000]	1056.600 [0.000]
$Q^2(12)$	601.050 [0.000]	604.880 [0.000]	471.300 [0.000]	831.120 [0.000]

Note:

- Figures in parentheses and in squared brackets indicate t-statistics and significance levels, respectively.
- ** and * denotes significance at 1% and 5% critical value levels, respectively.
- Adj. R^2 is the adjusted R-squares of the regression.
- Q(12) and $Q^2(12)$ are the Ljung-Box Q statistics of the raw series and of the squared series, distributed as $\chi^2(12)$ under the null hypothesis of nonserial correlation with lags up to 12.
- Volatility h_t is defined as the one-step ahead conditional variance of the freight rate, computed from a well-specified AR-GARCH model.
- FS , fleet size; IP , industrial production; BP , bunker price

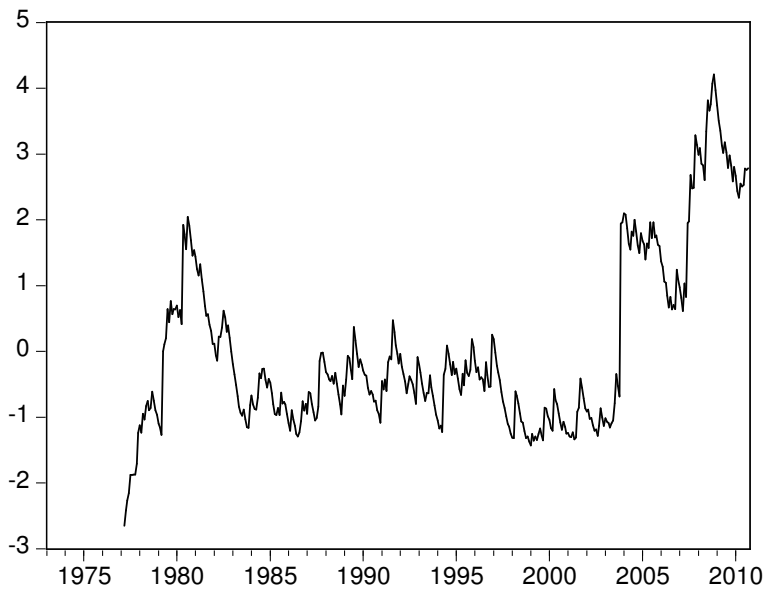
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Figure 1
Shipping supply and demand functions



Source: Maritime Economics (Stopford, 1997)

Figure 2
Panamax dry bulk spot rate (SPR_p) volatility (January 1973- October 2010)



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Figure 3

Panamax dry bulk time-charter rate (TCR_p) volatility (January 1976- October 2010)

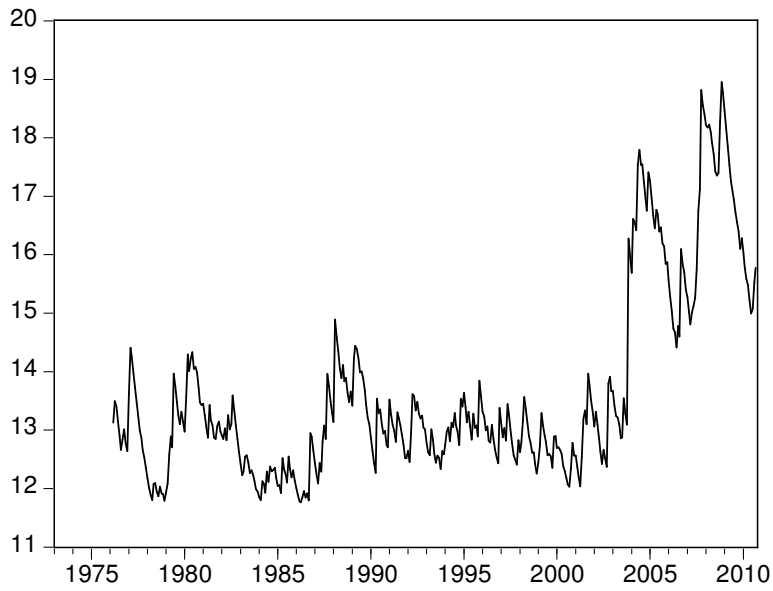
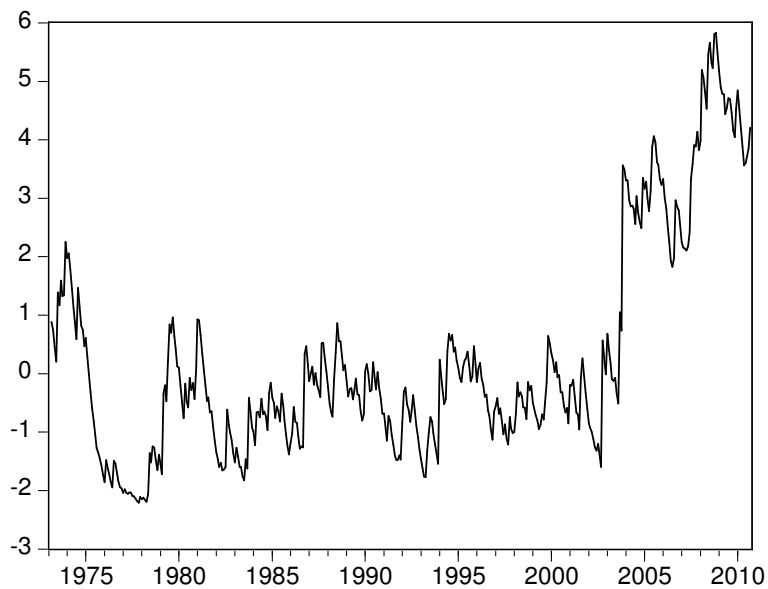


Figure 4

Capesize dry bulk spot rate (SPR_c) volatility (January 1973- October 2010)



Xu, J. J., Yip, T. L., & Marlow, P. B. (2011). The dynamics between freight volatility and fleet size growth in dry bulk shipping markets. *Transportation Research Part E: Logistics and Transportation Review*, 47(6), 983-991.

Figure 5

Capesize dry bulk time-charter rate (TCR_c) volatility (January 1977- October 2010)

