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Stationarity of Spot Freight Rates Considering Supply/Demand Effect

Abstract

The mean-reverting nature of freight rates is one of the important subjects in maritime economics. The classic understanding of maritime economics suggests that freight rate processes are mean-reverting and approaching to the level decided by demand/supply ratio. However, statistical tests on freight rate processes often reveal these processes are not stationary, which means the processes do not have mean-reverting nature. In this study, we investigated the mean-reverting nature of Panamax freight rates (Baltic Panamax 4T/C Average) for two "means": The former is for actual freight rates process itself, the latter is for deviation process of actual freight rates from estimated ones based on demand/supply ratio. AR (1) model can be applied both processes and their autoregressive coefficient φ was between 0 and 1. In the actual freight process, φ was close to 1 and a unit root test fails to reject the presence of a unit root. By contrast, in the deviation process, φ was sufficiently smaller than 1 and a unit root test rejects the presence of a unit root. The result can resolve the contradiction between two views on mean-reverting nature; if you focus on actual freight rates process itself and do not consider demand/supply, the process is non-stationary and does not have mean-reverting nature. If you focus on the deviation process of actual freight rates from the level decided by demand/supply ratio, the process is stationary and tends to approach zero.

Keywords: *(4-6 keywords) drybulk, market, stationarity.*

1. Introduction

The mean-reverting nature of freight rates is one of the important subjects in maritime economics. In addition, industrial analysts of shipping market pay attention on this issue, as it affects what kind of statistical methods they can use for freight market analysis.

In classic understanding of maritime economics, the drybulk shipping market is a competitive market where a freight is decided by demand/supply ratio. Based on this understanding,

when a freight rate deviates from the level determined by demand/supply ratio due to some market disruption factors, the deviation will disappear in the future and a freight rate will return to the level determined by the demand/supply ratio i.e. the freight rates process is mean-reverting. This understanding is in line with the empirical understanding of industry analysts. As a result, industry analysts carry out shipping market forecasts based on this understanding.

On the other hand, many preceding studies of drybulk shipping market based on modern econometric approach shows that the time-series of freight rates is non-stationary or is a unit root process. A unit root process can be expressed as below:

$Y_t = Y_{t-1} + c + \varepsilon_t$

Where c is constant and ε_t is white noise.

This definition shows that a unit root process is not mean-reverting. As many of financial indicators and commodity prices are unit root processes, it is not strange that the drybulk freight rates is also a unit rate process. However, the result that the drybulk freight rates process is not mean-reverting contradicts classic understanding of maritime economics and empirical understanding of industry analysts.

At the moment, industry analysts do not take this contradiction seriously. However, if the contradiction is real, their analyses may produce wrong results. A unit root (non-stationary) process and a mean-reverting (stationary) process have different characteristics and applicable statistical techniques. For example, regression analysis between two non-stationary processes produce a wrong result called 'spurious regression'.

Few previous studies focus on the contradictions. Given the importance not only in academic theories but also practices in the industry described above, it is necessary to resolve this contradiction.

The most appropriate way to resolve the contradiction is to introduce a new perspective that allows a freight rate can be both unit root process and mean reverting process. This is because, as described above, both views have firm backgrounds and hard to deny.

The possible perspective is that these two views focus on different aspects. A freight rate process is a non-stationary process, therefore freight rate is not mean-reverting by itself. Freight rates are basically decided by demand/supply ratio, therefore the deviation of actual freight rates from the estimated ones based on demand/supply ratio is mean-reverting. This

deviation was not investigated in preceding studies after 90s because of the lack of appropriate supply and demand data. Indeed, these supply and demand data exist in the shipping industry. However, handling these data requires expertise in industry analysis and the expertise was not provided to the academia.

The author is a shipping industry analyst and has expertise to handle supply and demand data suitable for this analysis. In past studies, the author has calculated the deviation of actual freight rates from estimated ones based on demand/supply ratio (Hayashi, 2019). This approach can be applied to the issue described above.

This study calculates the deviation of actual freight rates from estimated ones based on demand/supply ratio, then test whether the processes of actual/estimated freight rates and the deviation have a unit root or how strong their mean-reverting nature is. More precisely, this paper assumes the below model

Actual Freight rates (a) = Estimated freight rates based on demand/supply (b) + Deviation (c)

then tries to confirm that (a) is a non-stationary process but (c) is not.

The reminder of this paper is structured as follows: Section 2 introduces the preceding studies. Section 3 presents the approach and data profile. Section 4 presents the result of the statistical analysis. Section 5 presents discussions on the results. The final section concludes this paper.

2. Literature Survey

The history of models of drybulk shipping market is summarized in preceding survey papers, such as Goulielmos (2018a, 2018b, 2019) and Glen (2006). This paper focuses two groups of preceding studies: One is of papers using supply and demand data to explain or forecast market. The other is of papers to explain why and how freight rates process is mean-reverting or not.

Studies belonging to the first group were dominant in the early stage of shipping market modelling. These studies began with Tinbergen (1931, 1934) and Koopmans (1939), followed by Zannetos (1966), then peaked at Beenstock and Vergottis (1993). The results of these studies are incorporated into standard textbooks of maritime economics, such as Stopford (2009) or Karakitsos and Varnavides (2014).

However, after Beenstock and Vergottis (1993), studies of shipping market modelling using supply and demand are abandoned, except special studies such as testing the hypothesis of a past study with the data that became available.

In recent years, using AIS data as supply and demand data is attracting attention within academia. Although few papers have been published, such as Yang et al. (2019) and Adland, Jia and Strandenes (2017), the number of conference presentations has increased considerably.

On the industry side, market analyses based on supply and demand have been common as described above. These analyses are usually carried out within an organization and only the results are published to the outside. However, in recent years, information providers started to offer services which publish the logics of their market analyses to some extent. One notable example is The IHS Markit Freight Rate Forecast (IHS Markit, 2018).

As for studies belonging to the second category, many preceding studies carry out unit root tests for the freight rate processes they are going to investigate. The results vary. Some processes have a unit root, but others are not.

As for the studies on the reason how some freight rates processes have a unit root (and therefore are not mean-reverting) and others don't, Adland and Cullinane (2006) and Koekebakker, Adland and Sodal (2006) used non-parametric Markov diffusion model for tanker freight rates processes. The result is that freight rates are mean-reverting only in extreme markets and have a unit root during other periods.

3. Methodology

As described in chapter 1, this study assumes the below model

Actual freight rates (a) = Estimated freight rates based on demand/supply (b) + Deviation (c)

Then follow the below steps

- Obtain the formula to derive estimate freight rates from demand and supply
- Calculate estimated freight rates and their deviation from actual ones
- Examine the statistical characteristics of each time-series.

This study focuses on the market of Panamax size bulkers. This is because Panamax market is most liquid and competitive market among all vessel sizes (Capesize, Panamax Handysize and Handymax). Markets of Handymax and Handysize are divided into commodities and therefore less liquid than that of larger vessels. On the other hand, Capesize market depends

almost solely on iron ore trades, especially between Australia/Brazil and China. Also, a few big mining companies hold large trading shares and therefore have a strong influence on the market. Panamax market has two major cargoes (e.g. coal and grains) and their markets are integrated. Also, there are no players holding a large share such as in iron ore.

The examined period starts February 2009 when the market disturbance by Financial Crisis is over, and ends at May 2017.

The market indicator used in this study is logarithmic Baltic Panamax 4T/C in order to express exponential relationship between freight rates and demand/supply ratio.

The demand/supply indicator is a ratio of cargo volume to fleet capacity.

Cargo volumes are based on customs export statistics retrieved from IHS's online database "Global Trade Atlas". These volumes are the total of major commodities from major export countries, which listed in table 1:

Table 1 – Major export countries of Panamax cargoes

Commodity	Export Countries
Coking Coal	USA, Australia and Canada
Steam Coal	Australia, South Africa and Indonesia
Wheat	USA, Canada, Russia and Australia
Corn	USA, Argentina, Ukraine and Brazil
Soybean	USA, Brazil and Argentina

Fleet capacity is based on "Fleet Development (in DWT)" retrieved from Clarkson's online database "Shipping Intelligent Network".

Besides a ratio of cargo to fleet, the below factors will affect supply and demand conditions:

- Non-operational period of vessels, caused by drydock, laid-up and congestion
- Transport distance of each cargo (e.g. ton mile)
- Average speed of vessels.

This study does not include these factors. This is mainly because they are difficult to obtain over the investigated period. In addition, these factors change gradually and do not heavily

affect short-term deviation. However, if these data will become available, they should be included.

Based on above freight rates, supply and demand, we assume simple linear regression between freight rates and demand/supply ration as below.

Estimated freight rate (b) = α × (demand/supply ratio) + β

4. Analysis Result

First of all, obtained parameter α and β by simple regressions are 0.0902 and 2.2007, respectively. e.g.

Estimated freight rate = 0.0902 × (demand/supply ratio) + 2.2007

Figure 1. is a visual comparison of actual and estimated freight rates calculated by the above parameters. Figure 2. is the illustration of deviation of estimated freight rates from actual ones.

Figure 1. – Actual and estimated freight rates.

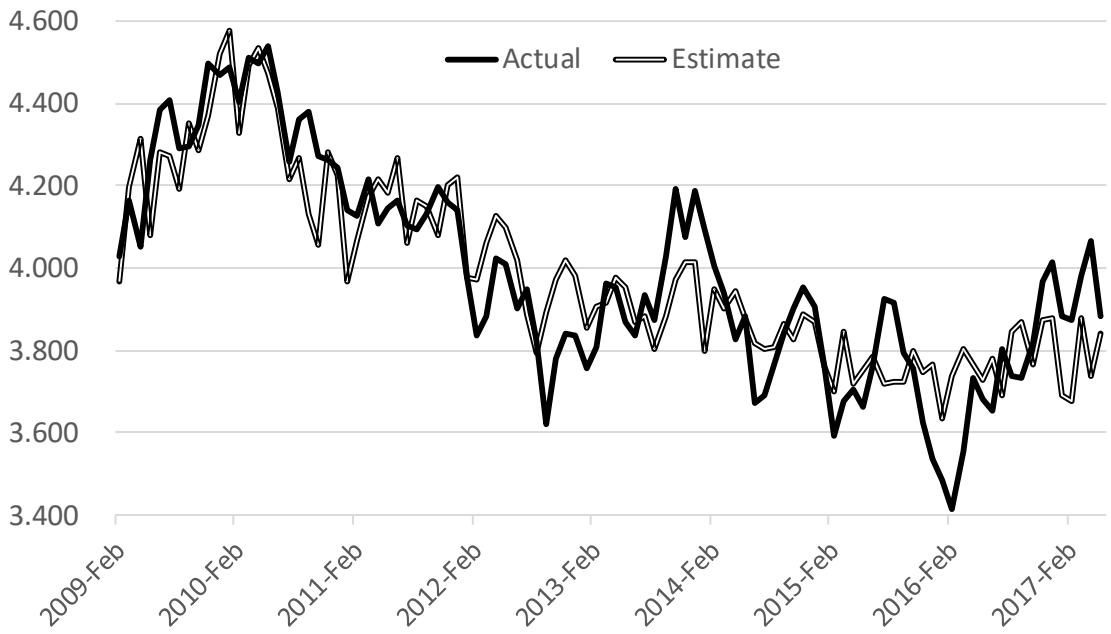
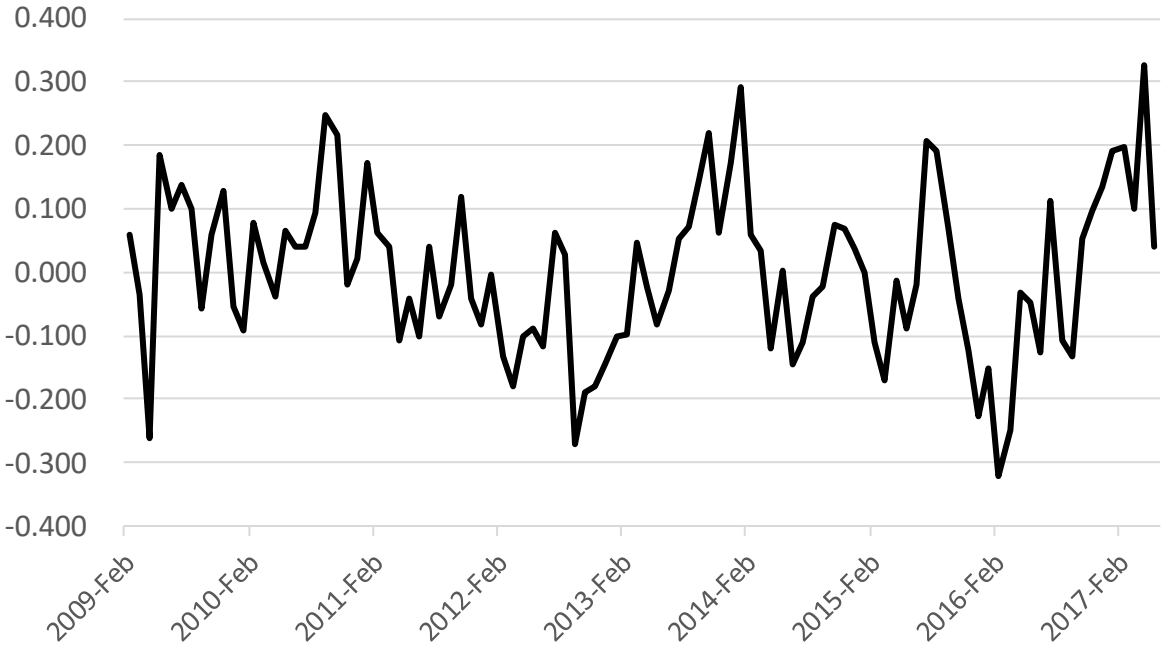


Figure 2. – Deviation of actual freight rates from estimates.



Given the above estimation, descriptive statistics for the time series are calculated as Table 2.

Table 2. – Descriptive statistics for actual and estimated freight rates.

	Actual Freight Rates	Estimated Freight Rates	Deviation
Numbers of observations	100	100	100
Mean	3.9898	3.9898	0.0000
Maximum	4.5390	4.5779	0.3251
Minimum	3.4150	3.6344	-0.3203
Std. Deviation	0.2602	0.2265	0.1280

Also, we performed stationarity tests of these three time-series. The test is conventional Augmented Dickey Fuller test with a constant and a trend. The lag length is selected by Schwarz Bayesian information criterion. The results are in Table 3.

The results in Table3 do not support the stationarity of actual and estimated freight rates. The results failed to reject the presence of a unit root at 10% level of significance. On the other hand, the result for the deviation process rejected the presence of a unit root at 5% level of significance.

Table 3. – ADF tests.

	Value	Lags
Actual Freight Rates	-2.496	4
Estimated Freight Rates	-2.303	4
Deviation	-3.723	4
Critical values - 1%	-4.052	
Critical values - 5%	-3.452	
Critical values - 10%	-3.153	

To investigate the detailed characteristics of mean-reverting nature, we applied AR (1) model to these processes. The models can be expressed as below:

$$R_t = \varphi \times R_{t-1} + \mu + \varepsilon_t$$

The parameters of these models are in Table 4.

Table 4. – Parameters of AR (1) models.

	Actual Freight Rates	Estimated Freight Rates	Deviation
Autoregression coefficient ϕ	0.9258	0.8849	0.5187
Intercept μ	3.6937	3.5305	0.0000
Variance of innovation $\sigma 2$	0.0098	0.0113	0.0121

Also, we tested autocorrelation and autocovariance of residual ε_t. The test method is Ljung-Box test. Tests for all three residuals rejected the presence of autocorrelation and autocovariance at 5% level significance.

5. Discussions about the results

As for the estimated freight rates from demand/supply ratio, we believe the estimation obtained in this study is good enough as a basis to investigate the deviation. Figure 1. shows that actual and estimate freight rates are almost moving together, including their peak and bottom values and timings. Figure 1. also illustrates a cyclical fluctuation with a length of 3 to 4 years. This cyclical fluctuation may be caused by the time lag between order and delivery of vessels, as discussed in Hayashi (2019). However, the fluctuation is small and partial autocorrelation is not observed in both actual freight rates and deviation. Therefore, we decided not to include this cyclical fluctuation in this study.

The actual and estimated freight rates and their deviation show statistical characteristics in line with the assumption of this study. Both actual and estimated freight rates are unit root processes, although their deviation is not. This means that actual and estimated freight rates are cointegrated.

The analysis using AR model supports this result. From the test results of autocorrelation and autocovariance ε_t of both actual freight rates can be regarded as white noises. Therefore, fitting AR (1) model for these two processes are valid. Comparing the values of φ, which shows a power of mean-reverting, φ of actual freight rates is greater than 0.9 but φ of deviation is about 0.5. Therefore, we can confirm actual freight rates has mean-reverting nature, but deviation does not.

6. Conclusion and Further Discussion

This study examined the stationarity and mean-reverting nature of freight rates. These issues are important for maritime economics and have been discussed for a long time. The outcome is that freight rates process itself is non-stationary and therefore not mean-reverting, while the deviation process of freight rates from estimation by demand/supply ratio is stationary and mean-reverting. This outcome is meaningful because it can integrate two inconsistent views on freight rates.

In future studies, other frequency (especially shorter frequency than this study) should be examined whether they will produce the same outcome. Because of the spread of AIS data in recent years, some of supply and demand information, such as laden/ballast ratio, can be obtained almost real-time and with higher frequency. Comparing the outcome of such future studies with this study may provide not only the difference between frequencies but also the difference in characteristics of supply and demand information between AIS data and traditional methods (trade volume and fleet capacity).

It is also important to extend the analysis to markets of other ship sizes and types, and other time periods. As described above, Panamax market is most perfectly competitive market. Therefore, markets of other sizes and types may indicate different characteristics. As for time period, the period examined in this study is when the drybulk market was stable and relationship between freight rates and demand/supply ratio was consistent. By including the change of the relationship between freight rates and demand/supply ratio, it will be possible to examine longer time periods containing structural market changes.

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