Analysis of Baltic Dry Index based on GARCH Model

Yuliang Zhang¹, Gang Zhao²

¹College of Transport and Communications, Shanghai Maritime University, Shanghai 201306, China;
²College of Transport and Communications, Shanghai Maritime University, Shanghai 201306, China.

Abstract

In order to grasp the trend of the international dry bulk shipping market and the fluctuation characteristics of the Baltic Dry Index (BDI), this study takes BDI daily yield series as the research object, and finally selects to establish GARCH (1,3) based on GED distribution by comparing the parameter quality of each model, it is found that the model well reflects the effect of volatility clustering and the characteristics of peak and fat tail of daily return series, and eliminates the conditional heteroscedasticity of residual series. Based on the model, the short-term static prediction is satisfactory. The EGARCH model is used to discuss the impact of external information on the shipping market, and the result shows that in the sample period, positive news has a greater impact on the volatility of daily yield than negative news.

Keywords

BDI daily return series; GARCH model; volatility.

1. Introduction

The Baltic Freight Index (BFI) was released in 1985 by the Baltic Exchange in London, England. The index is based on several international dry bulk shipping routes and their importance and weight in the shipping market. In 1999, the Baltic Dry Index (BDI) was released by the Baltic Exchange, which replaced the BFI index. In the decade that followed, its structure and methods of calculation were constantly updated. On July 1, 2009, the Baltic Exchange takes into account the equal weight of Capesize, Panamax, Handysize and Handymax time charter market indices in the index and made it become the most representative dry bulk shipping freight index on the market.

As the most representative freight index in the global dry bulk shipping market, BDI not only reflects the fluctuation of the international dry bulk shipping market from the perspective of trading volume supply and demand, to a certain extent, it also reflects the deepening integration of world trade and the economic development of various countries. BDI is not only the barometer of international shipping market, but also the leading index of international trade and the bellwether of world economy. As the main cargo of international dry bulk cargo transportation, iron ore, coal, grain and other bulk cargo are indispensable resources for the stable economic development of all countries and the protection of national economy and people's livelihood. Therefore, the international dry bulk transportation market is the important influence factor of the world economic development. The influence of many factors, such as politics, economy and market supply and demand, on the freight rate of dry and bulk cargo is often fluctuated, which makes it difficult for the enterprises concerned in the transportation of dry and bulk cargo to make business decisions, unable to make timely and accurate adjustments. For example, in 2008, the dry bulk shipping market experienced huge fluctuations, the first half of the year was good, BDI reached 11,793 points on May 20, a new
historical record; however, affected by the financial crisis, BDI fell in the second half of the year, hitting a record low of 663 on December 5, a drop of 94.4%. Under the circumstance of huge fluctuation of freight rate, shipping enterprises want to avoid market risk and reduce loss, so it is of great significance to judge correctly the trend of dry bulk freight and grasp the fluctuation characteristics of bulk dry freight.

2. Research on the Volatility of Dry Bulk Freight Index

Kavussanos and Amir (2001) [1] established single-variable seasonal autoregressive integral moving average model, multi-variable seasonal cointegration vector autoregressive (Var) model and show that the dry bulk cargo market has seasonal volatility. Jing, Marlow and Hui (2008) [2] used GARCH and EGARCH to analyze the volatility characteristics of dry bulk freight rates from March 1,1999 to December 23,2005 in three types: Capesize, Panamax and Handysize, the results show that the external shocks strengthen the different types of dry bulk market, and the symmetry is not the same.

Lu, Zhao and Hu (2008) [3] analyzed the stability and Heteroscedasticity of BDI, and found that BDI had obvious volatility aggregation effect by GARCH model, used EGARCH model to get that the "good news" had more influence on the volatility than the equal amount of "bad news". Nie and Li (2009) [4] studied the factors theory of international dry bulk shipping market, and used ARFIMA model to analyze the long memory of BDI, the results show that the international dry bulk freight index has a long memory. Fan (2014) [5] used the GARCH family model to study the volatility rule and forecast of BDI. Sha (2015) [6] thought that the static forecasting error of BDI based on different distribution was very small, and the forecasting precision of GARCH model to short-term freight fluctuation was high. Li (2016) [7] studied the fluctuation law of China’s coastal dry bulk transportation market by using the stochastic volatility model, and found that it had high volatility persistence and obvious reverse leverage effect in the freight market.

3. Data Selection and Processing

The raw data for this research are taken from the Baltic Dry Index published by the Baltic Exchange, from Clarkson. The data range in the sample is from July 1,2009 to April 30,2020, excluding the non-trading days in the period, including a total of 2706 observation days data, constitutes BDI daily freight index sequence, recorded as $P_t$, to build a model. The out-of-sample data range is from May 1,2020 to May 28,2020, including 20 observation days for static prediction. The graph describing $P_t$ is as follows:

![Fig 1. BDI data curve](image-url)
Using the ADF test method based on SC (Schwartz Criterion), the following graph shows the results of ADF unit root test using EViews:

![ADF Test Graph]

Fig 2. BDI sequence unit root test results

From Fig. 2, according to the selection criteria of SC lag period, when the maximum lag period is 27, the unit root test value of BDI daily rate index sequence \((P_t)\) is -3.496946, which is less than the critical value of 5% and 10%, but more than the critical value of 1%, therefore, the null hypothesis that sequence \((P_t)\) has a unit root can not be rejected at the level of 1%. Combined with the data curve of the series, we can see that the BDI index fluctuated greatly in the sample period. In order to show the volatility of dry bulk freight index correctly, this paper chooses the daily rate of return series (change rate of BDI daily data) as the research object. The return series has better statistical characteristics than the index series and has certain guidance to the measurement of investment opportunity. The daily rate of return of BDI is obtained by logarithmic first order differential treatment of \(P_t\), record as \(R_t\),

\[
R_t = \ln P_t - \ln P_{t-1}
\]

The logarithmic first order difference is used to define the rate of return for the following reasons:

1. Using a logarithm form does not change the properties and correlation of the data, but compresses the scale of the variables, the trend of growth curve of series can be transformed into linear trend in the fluctuant data, which makes the data more stable.
2. It is easy to eliminate the heteroscedasticity of the original data.
3. The difference between the logarithms of the two points is approximately equal to the rate of change of the change, in the form of

\[
R_t = \Delta \ln P_t = \ln P_t - \ln P_{t-1} = \ln \frac{P_t}{P_{t-1}} = \ln \frac{P_t - P_{t-1} + P_{t-1}}{P_{t-1}} = \ln \left(1 + \frac{\Delta P_t}{P_{t-1}}\right) \approx \frac{\Delta P_t}{P_{t-1}}
\]

The basic statistical analysis of the daily Return Series \(R_t\) of BDI shows as follows:
According to the basic statistical characteristics of BDI daily rate of return series, we can know:

1. The average and median of daily rate of return between July 1, 2009 and April 30, 2020 are all negative, which shows that due to the financial crisis in 2008 and other negative effects, dry bulk cargo demand has shrunk, the shipping market has remained depressed in recent years, leading to a downward trend in freight rates.

2. The kurtosis is 5.228762, greater than the normal distribution of the kurtosis 3, it is shown that the BDI rate of return series has the characteristics of peak and fat tail of financial time series.

3. Skewness of 0.158611 is greater than 0, which indicates the asymmetry of the series and the right skewness of the series.

4. The value of probability of JB statistics is 0, which indicates that the series does not obey normal distribution.

5. The variation range of the sequence is large, which shows the effect of wave aggregation.

4. Model Building

4.1. Test on the Stability of Daily Return Series of BDI

As you can see from figure 4, yields fluctuate around 0, with no obvious upward or downward trend. Based on SC criterion, ADF test is used to test the stability of $R_t$, and the result is as follows:
As can be seen from Fig. 5, according to the selection criteria of SC lag, when the maximum lag is 27, the unit root test value of the daily rate of return series is -17.23950, which is far less than the critical value at the level of 1%, 5%, 10%, and the associated probability is 0, therefore, the null hypothesis that BDI daily rate of return has unit root is rejected at the level of 1%, 5% and 10%, that is, the BDI daily rate of return is stable.

4.2. Autocorrelation Test of Daily Return Series of BDI

To analyze the stochastic process model of return series and judge its autocorrelation, generally by observing the autocorrelation function graph and the partial autocorrelation function graph to make qualitative judgment, judging the tail and the truncation phenomenon, simultaneously observes the Ljung-Box Q test statistic, whether the time series has significant autocorrelation or not. The result of examination is shown in figure 6.

It is found that ACF (autocorrelation graph) of daily return series of BDI is tailed, and PACF (partial correlation graph) is truncated, which shows that daily return series satisfies AR (p) regression model, the value of the associated probability of Q statistic is always 0, which indicates that the probability of accepting the null hypothesis that the daily rate of return series has no autocorrelation is 0, and that the daily rate of return series has autocorrelation. Through the above-mentioned test conclusions, it can be confirmed that the former rate of return has an impact on the current rate of return, the volatility of the freight index is transmissive, and the influence of external information on the shipping market will not only cause the present rate of return to fluctuate violently, in the later period, the rate of return will fluctuate at a higher level, and the fluctuation range is similar in different periods.
4.3. ARCH Effect Test on Daily Return Rate Series of BDI

Firstly, the average value model of daily rate of return series is established. Judging from 2.2, $R_t$ satisfies the AR (2) form of mean value regression model. In order to make the goodness of fit reach a better level, AR (1) and AR (2) models are established for daily rate of return series respectively, the fitting parameters AIC, SC and HQ were calculated and compared.

<table>
<thead>
<tr>
<th>Tab 1. Comparison of AR(p) mean model parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIC</td>
</tr>
<tr>
<td>AR (1)</td>
</tr>
<tr>
<td>AR (2)</td>
</tr>
</tbody>
</table>

It can be seen from Table 1 that the AIC value, SC value, and HQ value of the AR (2) model are all smaller than the AR (1), so the average equation is determined as:

$$ R_t = 0.800889R_{t-1} - 0.121273R_{t-2} + \epsilon_t $$ (3)

Observing Figure 7, the associated probability value of each coefficient statistic is less than 0.05, which shows that the statistical index accords with the requirement of the model through the significance test of confidence level at 95% level. The daily rate of return obtained by formula is positively correlated with the first and third order of delay and negatively correlated with the second order of delay.

To test whether the residual sequence of the mean model has ARCH effect, it is necessary to judge whether the residual sequence has conditional heteroscedasticity. First observe the residual plot of the BDI daily rate of return series. As shown in Figure 8, there is a phenomenon of volatility clustering, and the sequence may have conditional heteroscedasticity; Lagrange multiplier test is used in EViews, that is, ARCH-LM. The results are shown in Figure 9. When the lag period reaches the 20th order, the Obs*R-squared value (LM statistic) is 249.2309, the accompanying probability value is 0, and the residual sequence is not rejected at a 1% significance level. The null hypothesis of heteroscedasticity indicates that there is an ARCH effect in the residual sequence, and there is a higher-order ARCH effect, namely the GARCH effect. Therefore, consider using the GARCH model to eliminate heteroscedasticity.
4.4. Modeling and Prediction of GARCH Model

To test whether the residual sequence of the mean equation obeys normal distribution, the basic statistical characteristics of the residual sequence are shown in figure 10:

![Fig 10. Basic statistical characteristics of residual sequence](image)

The kurtosis value is 9.577715, which is larger than the kurtosis value 3 of the normal distribution, and has the characteristic of sharp peak and thick tail. The Jarque-Bera statistic is 4882.811, and the associated probability is 0, which indicates that the residual sequence refuses to obey the null hypothesis of the normal distribution.

In the analysis of financial time series, the choice of order and residuals of GARCH model mainly follows logarithmic likelihood criterion, AIC criterion and SC criterion. The bigger Log likelihood is, the smaller Akaike Info Criterion and SC (Schwarz Criterion) are, the more accurate the model is.

Finally, the GARCH (1, 3) is selected, considering AIC, SC criterion, model parameters and model concision. Because the residuals do not obey normal distribution, we need to establish GARCH models based on normal distribution, t distribution and generalized error distribution (GED) for residuals $\epsilon_t$ to compare their advantages and disadvantages. The model structure is as follows:
Tab 2. GARCH model degree selection

<table>
<thead>
<tr>
<th>GARCH (p, q)</th>
<th>AIC</th>
<th>SC</th>
<th>Log likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>GARCH (1,1)</td>
<td>-5.496666</td>
<td>-5.485748</td>
<td>7433.744</td>
</tr>
<tr>
<td>GARCH (1,2)</td>
<td>-5.517639</td>
<td>-5.504538</td>
<td>7463.089</td>
</tr>
<tr>
<td>GARCH (1,3)</td>
<td>-5.525543</td>
<td>-5.510258</td>
<td>7474.771</td>
</tr>
<tr>
<td>GARCH (2,1)</td>
<td>-5.499766</td>
<td>-5.486665</td>
<td>7438.934</td>
</tr>
<tr>
<td>GARCH (2,2)</td>
<td>-5.527824</td>
<td>-5.512540</td>
<td>7477.855</td>
</tr>
<tr>
<td>GARCH (2,3)</td>
<td>-5.529108</td>
<td>-5.511640</td>
<td>7480.589</td>
</tr>
<tr>
<td>GARCH (3,1)</td>
<td>-5.512131</td>
<td>-5.496846</td>
<td>7456.645</td>
</tr>
<tr>
<td>GARCH (3,2)</td>
<td>-5.514087</td>
<td>-5.496619</td>
<td>7460.289</td>
</tr>
<tr>
<td>GARCH (3,3)</td>
<td>-5.528787</td>
<td>-5.509135</td>
<td>7481.156</td>
</tr>
</tbody>
</table>

\[
R_t = C_1 R_{t-1} + C_2 R_{t-2} + \epsilon_t
\]

\[
\sigma_t = \alpha_0 + \alpha_1 \epsilon_{t-1} + \alpha_2 \epsilon_{t-2} + \alpha_3 \epsilon_{t-3} + \beta_1 \sigma_{t-1}
\]

Tab 3. BDI daily return series estimated by GARCH (1,3) model

<table>
<thead>
<tr>
<th>parameter</th>
<th>normal distribution</th>
<th>t distribution</th>
<th>GED distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_1</td>
<td>0.918523</td>
<td>0.906256</td>
<td>0.897727</td>
</tr>
<tr>
<td>C_2</td>
<td>-0.186380</td>
<td>-0.168804</td>
<td>-0.166008</td>
</tr>
<tr>
<td>\alpha_0</td>
<td>9.43E-07</td>
<td>3.13E-06</td>
<td>2.13E-06</td>
</tr>
<tr>
<td>\alpha_1</td>
<td>0.276917</td>
<td>0.399417</td>
<td>0.325876</td>
</tr>
<tr>
<td>\alpha_2</td>
<td>-0.160152</td>
<td>-0.207621</td>
<td>-0.179223</td>
</tr>
<tr>
<td>\alpha_3</td>
<td>-0.091131</td>
<td>-0.104419</td>
<td>-0.091343</td>
</tr>
<tr>
<td>\beta_1</td>
<td>0.972744</td>
<td>0.919851</td>
<td>0.941802</td>
</tr>
<tr>
<td>\alpha + \beta</td>
<td>0.998378</td>
<td>1.007228</td>
<td>0.997112</td>
</tr>
<tr>
<td>AIC</td>
<td>-5.525543</td>
<td>-5.707635</td>
<td>-5.686298</td>
</tr>
<tr>
<td>SC</td>
<td>-5.510258</td>
<td>-5.690167</td>
<td>-5.668830</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>7474.771</td>
<td>7721.869</td>
<td>7693.032</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.510382</td>
<td>0.511310</td>
<td>0.512328</td>
</tr>
</tbody>
</table>

According to the log likelihood criterion, AIC Criterion, SC Criterion and the significance of parameters, the distribution of the best fitting degree is selected. According to Table 3, the AIC and SC values of t distribution and GED distribution are smaller than normal distribution, Log likelihood ratio is larger than normal distribution, and the R-squared value of goodness of fit is higher. The t distribution of \( \alpha + \beta = 0.399417 - 0.207621 - 0.104419 + 0.919851 = 1.007228 > 1 \), the sequence does not satisfy the wide stationary condition, but the GED distribution of \( \alpha + \beta = 0.325876 - 0.179223 - 0.091343 + 0.941802 = 0.997112 < 1 \), satisfies the parameter constraint, so the distribution is finally selected as the residual distribution to model, the fitted GARCH (1,3) expression is as follows:

\[
R_t = 0.897727 R_{t-1} + -0.166008 R_{t-2} + \epsilon_t
\]

\[
\sigma_t = 2.13 \times 10^{-6} + 0.325876 \epsilon_{t-1} - 0.179223 \epsilon_{t-2} - 0.091343 \epsilon_{t-3} + 0.941802 \sigma_{t-1}
\]

After modeling, the residual series are tested again by LM test to check whether GARCH model eliminates the conditional heteroscedasticity of the series. The results are shown in Table 4.
Tab 4. ARCH-LM test results after modeling

<table>
<thead>
<tr>
<th>lag degree</th>
<th>LM statistic</th>
<th>associated probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.074993</td>
<td>0.7842</td>
</tr>
<tr>
<td>2</td>
<td>0.680279</td>
<td>0.7117</td>
</tr>
<tr>
<td>3</td>
<td>1.071582</td>
<td>0.7839</td>
</tr>
<tr>
<td>4</td>
<td>1.073636</td>
<td>0.8984</td>
</tr>
<tr>
<td>5</td>
<td>1.262863</td>
<td>0.9387</td>
</tr>
<tr>
<td>6</td>
<td>1.269687</td>
<td>0.9733</td>
</tr>
<tr>
<td>7</td>
<td>2.210538</td>
<td>0.9473</td>
</tr>
<tr>
<td>8</td>
<td>2.250983</td>
<td>0.9723</td>
</tr>
<tr>
<td>9</td>
<td>2.408910</td>
<td>0.9832</td>
</tr>
<tr>
<td>10</td>
<td>2.577745</td>
<td>0.9897</td>
</tr>
<tr>
<td>15</td>
<td>4.451566</td>
<td>0.9958</td>
</tr>
<tr>
<td>20</td>
<td>5.881239</td>
<td>0.9990</td>
</tr>
</tbody>
</table>

It can be seen that with the increase of the lag degree, the associated probability of LM statistic is greater than 0.05, and it is accepted that there is no conditional heteroscedasticity in the residual sequence of BDI return, and the GARCH (1,3) model under GED distribution is feasible. The sum of ARCH term coefficients (α) and GARCH term coefficients (β) is a parameter reflecting the volatility of BDI return series. The sum of ARCH term coefficients reflects the magnitude of the fluctuation when the series is impacted, and the larger the fluctuation is, the more rapid the fluctuation response is, the bigger the sequence, the stronger the memory of the shock wave. In the GARCH (1,3)-GED model of the daily return of BDI, the value of α + β is very close to 1, which indicates that when the shipping market is impacted by external shocks, the volatility of BDI is violent and lasts for a long time. The value is as high as 0.941802, which indicates that the fluctuation has a strong memory, and the influence decays slowly, and is not easy to be eliminated in a short time.

Using the GARCH (1, 3) model of the GED distribution of the BDI daily return rate series that has been obtained, the static prediction of the return rate is performed on the 20 data outside the sample. The comparison between the predicted value and the actual value is shown in Fig.11:

![Fig 11. Comparison of actual and predictive BDI daily rate of return](image)

It can be seen intuitively from Figure 11 that the prediction effect is better. To specifically test the prediction error, the Root Mean Square Error (RMSE) is used as the model prediction evaluation index. The calculation formula of RMSE is:
\[ RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (\hat{y}_i - y_i)^2} \]  

Among them, \( \hat{y}_i \) represents the forecast value of BDI daily rate of return, and \( y_i \) represents the actual value of daily rate of return series. Through calculation, the RMSE result of the prediction is 0.016775, which is within the allowable error range, and the model prediction error is small.

### 4.5. Analysis of Leverage Effect of BDI Daily Rate of Return

There is often asymmetric leverage effect in financial time series, that is, positive news and negative news have different influence on price fluctuation. The influence of interference term on conditional variance in GARCH model is symmetric, so it is not suitable to describe the asymmetric effect of external information on financial market volatility. In order to reflect the asymmetry of financial market fluctuation, Nelson (1991) put forward index GARCH model (EGARCH) on the basis of GARCH model, and used EGARCH model to model the daily return series of BDI, which can analyze the leverage effect of BDI Index. The Model of \( R_t \) is EGARCH (1,1). The residuals are based on GED distribution. The fitted model is:

\[
\begin{align*}
R_t &= 0.891765R_{t-1} - 0.158501R_{t-2} + \varepsilon_t \\
ln\sigma_t^2 &= -0.862616 + 0.330804 \frac{\varepsilon_{t-1}}{\sigma_{t-1}} + 0.057572 \frac{\varepsilon_{t-1}}{\sigma_{t-1}} + 0.925659ln\sigma_{t-1}^2
\end{align*}
\]  

(7)

The parameters all pass the significance test at the 95% confidence level, indicating that the model has a significant leverage effect. Equation (7) shows that, within the sample interval, when positive news appears in the shipping market, it will have an impact of 0.388375 (=0.330803+0.057572) times on the logarithm of the variance of the BDI daily rate of return, while negative news will bring 0.273232 (=0.330804-0.057572) times the impact, which shows that between 2009 and 2020, the BDI index fluctuations caused by positive news in the dry bulk shipping market were greater than those caused by equal amounts of negative news.

### 5. Conclusion

This paper analyzes the Baltic Dry Index data from July 1, 2009 to April 30, 2020, and concludes the following conclusions:

(1) The logarithmic first order differential processing of BDI sequence shows that the daily return sequence of BDI is stable, which does not obey normal distribution and has the characteristic of peak and fat tail, and the result of autocorrelation test shows that the sequence has autocorrelation, the former rate of return has an effect on the present rate of return, and the fluctuation of the freight index is transmissive, that is, the influence of external information on the shipping market will not only cause the present rate of return to fluctuate violently, and later the rate of return will therefore have a higher level of volatility.

(2) ARCH-LM test results of BDI daily return series are significant, there is high-order ARCH effect, which is suitable for AR (2) mean value model, and GARCH (1,3) model based on GED distribution has the best fitting effect, the conditional Heteroscedasticity of residuals can be eliminated, and the characteristic of peak and fat tail of sequences can be embodied.

(3) In the GARCH (1,3)-GED model of BDI daily rate of return, the value of parameter \( \alpha + \beta \) is very close to 1, indicating that during 2009-2020, when the shipping market was subjected to external shocks, BDI fluctuated violently and lasted for a long time. The fluctuation characteristics of the current period have a great continuation trend; the \( \beta \) value is as high as 0.941802, indicating that the fluctuation has a strong memory, and the impact decay rate is slow, and it is not easy to be eliminated in a short time.
The static prediction of GARCH (1,3) model is feasible for the short-term prediction of BDI daily return series, and RMSE is small.

Through EGARCH modeling analysis, the fluctuation of the BDI caused by positive news in the dry bulk shipping market from 2009 to 2020 was greater than the fluctuation caused by the same amount of negative news. This reflects to a certain extent that the market sentiment has a high tendency to rebound after a long period of downturn.

References


