# VaR Calculation and Validity Test of Shanghai Stock Exchange Index and Hong Kong Hang Seng Index under ARCH effect

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**Abstract.** This paper measures the data from January 4, 2006 to June 30, 2016, and finds that there are ARCH effects in A-share, Bshare, indices of Shanghai Stock Exchange and Hang Seng Index. Therefore, the GARCH family models are established under the assumptions of normal distribution and t- distribution respectively, and the VaR values are calculated. By Back-test test, the validity of VaR is compared, and it is found that both Shanghai stock market and Hang Seng index are suitable for GARCH family model with t-distribution, and there are risk aggregation and information asymmetry in stock market. And this study has a certain reference significance for the investors in the current Stock Connect between Shanghai and Hong Kong. Investors

## Introduction

The party's 19th CPC National Congress report calls for:"Guarding against the bottom line of systemic financial risk," and General Secretary Xi Jinping repeatedly stressed that "Financial security is an important part of national security, accurately judging the hidden risks is the premise to ensure the financial security". VaR method is a comprehensive risk quantitative analysis method which is widely accepted by the international financial circles at present.

In this paper, we consider the portfolio with only a single stock index, and discuss the parameter method of VaR calculation, especially the empirical analysis of VaR model. On the basis of synthesizing the previous scholars' views and the increasing sample size, the dynamic VaR values of A share index, B share index and Hang Seng index of Shanghai Stock Exchange are calculated by using the representative GARCH, EGARCH and PARCH models under the assumption of normal distribution and distribution, respectively. The results are analyzed and compared, and the return test is used to answer the following questions:

How do different GARCH models affect the VaR value in the estimation results?

Is there a significant difference in the calculation of VaR values in the same model under different distribution assumptions?

How is the effectiveness of VaR in predicting the risk value of Shanghai A-share Index and Shanghai B-share Index?

The characteristics of VaR of Hong Kong's Hang Seng Index.

## An Empirical Analysis of Risk Measurement in China and Hong Kong Stock Markets

### Data Selection and Time Selection.

Analyzing the selection of sample sequence. According to the research of domestic scholars in recent years, most of them are the analysis and comparison of the Shanghai Composite Index and Shenzhen Composite Index, and come to an unanimous conclusion that the risk of Shenzhen Composite Index is greater than that of Shanghai Composite Index. This paper studies the Shanghai stock market and the Hong Kong stock market. In the Shanghai Stock Exchange, according to the classification of stock index, we choose Shanghai Stock Exchange A and Shanghai B stock to analyze their return volatility and risk value prediction. In the Hong Kong stock market, we chose the Hang Seng Index, the most influential stock index, which reflects the price trend of the Hong Kong stock market.

Selection of analysis time. Although Shanghai Stock Exchange A shares was released since February 21, 1992, Shanghai B shares was officially released since August 17, 1992;However, due

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to the small number of stocks in circulation at the beginning, the imperfect trading system and the strong speculative nature of the stock market, the stock market was extremely volatile. After the year of 1996 and 1997, the fluctuations tended to stabilize. In order to further improve our stock market, China completed the stock reform in 2005.

For comparison, we choose Shanghai Stock Exchange A, Shanghai B and Hang Seng Index with the same VaR forecast range of 600.

Combined with the above factors, the entire period of data analysis was selected from 4 January 2006 to 30 June 2016;In order to forecast, we take 1949 samples of Shanghai Stock Exchange A and B from January 4, 2006 to January 14, 2014, and Hang Seng Index from January 3, 2006 to January 22, 2014, with a total of 1950 data, to predict 600 VaR values by June 30, 2016.Shanghai Stock Exchange A, B stock index, Hang Seng index data are from Wind Information. The software of data processing and analysis is Eviews8.0 and excel.

**Basic Analysis of Data.**

The logarithmic rate of return for each index is:

$r_t = \ln P_t - \ln P_{t-1}$

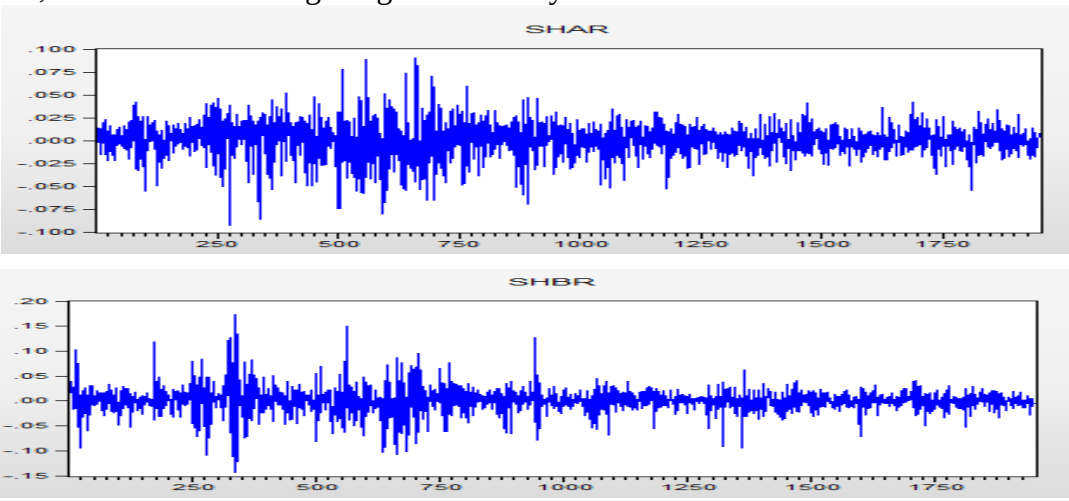
Where， $P_t$ for each index daily closing price； $P_{t-1}$ For the previous day's closing price。

Among them, $P_t$ is the daily closing price of each stock index; $P_{t-1}$ is the closing price of the previous day.

Table 1 basic statistics of logarithmic rate of return by index

| data | max | min | mean | Std. Dev.. | Skewness | Kurtosis | J-B | P |
|---|---|---|---|---|---|---|---|---|
| Shanghai Stock Exchange A | 0.0903 | -0.0926 | 0.0003 | 0.0176 | -0.3866 | 6.2428 | 902.0316 | 0 |
| Shanghai Stock Exchange B | 0.1740 | -0.1429 | 0.0007 | 0.0239 | 0.0949 | 10.6401 | 4740.709 | 0 |
| Hang Seng | 0.1341 | -0.1358 | 0.0002 | 0.0174 | 0.0472 | 11.0826 | 5409.407 | 0 |

Table 1 is the basic statistical characteristics of each index. From the deviation, kurtosis and J-B detection value in the table, we can see that several indexes do not accord with normal distribution. By using histogram (figure 2), we can further know that the income of each index has the characteristics of peak and thick tail.Figure 1 shows a straight line of logarithmic returns for each index, reflecting the aggregation of volatility and the volatility of the Hang Seng Index in Hong Kong in 2008, after which the Hang Seng Index slowly levelled off.



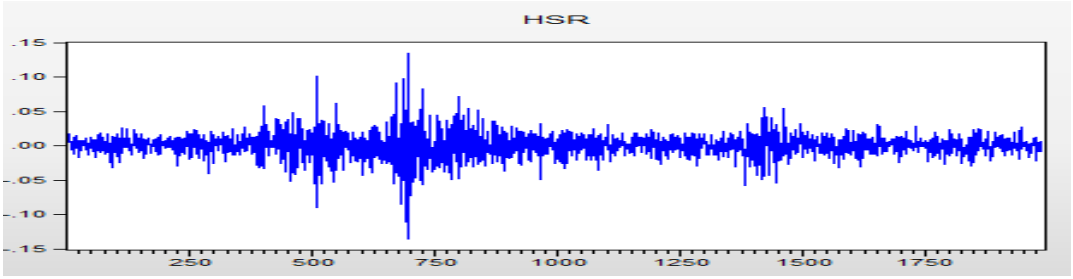



Figure. 1 A Shares, B Shares of Shanghai Stock Exchange and Hang Seng Index logarithmic income straight Line Chart

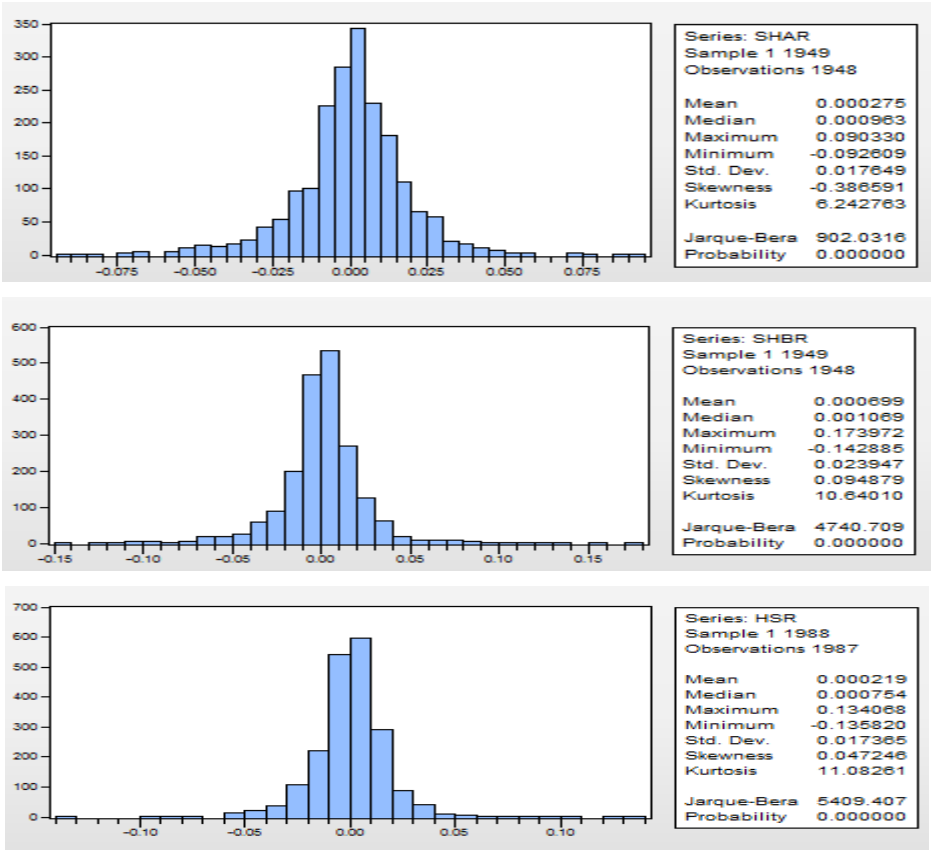



Figure. 2 logarithmic income histogram of A Shares, B Shares of Shanghai Stock Exchange and Hang Seng Index

Other statistical characteristics of each index:

The logarithmic return rate of each stock index is stable through ADF unit root test, and the logarithmic return rate of Shanghai A-share, Shanghai B-share and Hang Seng Index are all stable;

The logarithmic rate of return of each index is autocorrelation. For Shanghai Stock Exchange A-share, Shanghai B-share, Hang Seng Index to seek autocorrelation and partial autocorrelation, the correlation between the logarithmic yield of the three indexes is not significant, almost irrelevant. Therefore, the model is established as follows:$r_t = c_0 + \varepsilon_t$

The heteroscedasticity test of the yield of each index for several days.This is because it can be seen intuitively that the daily yield of Shanghai A-share, Shanghai B-share and Hang Seng Index has volatility and aggregation (see figure 1), and the squared residuals are correlated (see figure 3), there may be heteroscedasticity, Therefore, the Lagrange multiplier test (LM heteroscedasticity test) is applied to the three indices. The results are as follows: The original assumption is that:No ARCH effect

Table 2 The original assumption is that:No ARCH effect

| Index name | Lag order | ARCH statistics | P value | Test results |
|---|---|---|---|---|
| Shanghai Stock Exchange A shares | 18 | 44.29705 | 0.0005 | Refuse |
| Shanghai B shares | 4 | 22.48496 | 0.0002 | Refuse |
| Hang Seng Index | 10 | 23.63904 | 0.0084 | Refuse |

From the results above, we verify that the ARCH effect exists in all three stock indices,so We establish ARCH family model for volatility prediction.

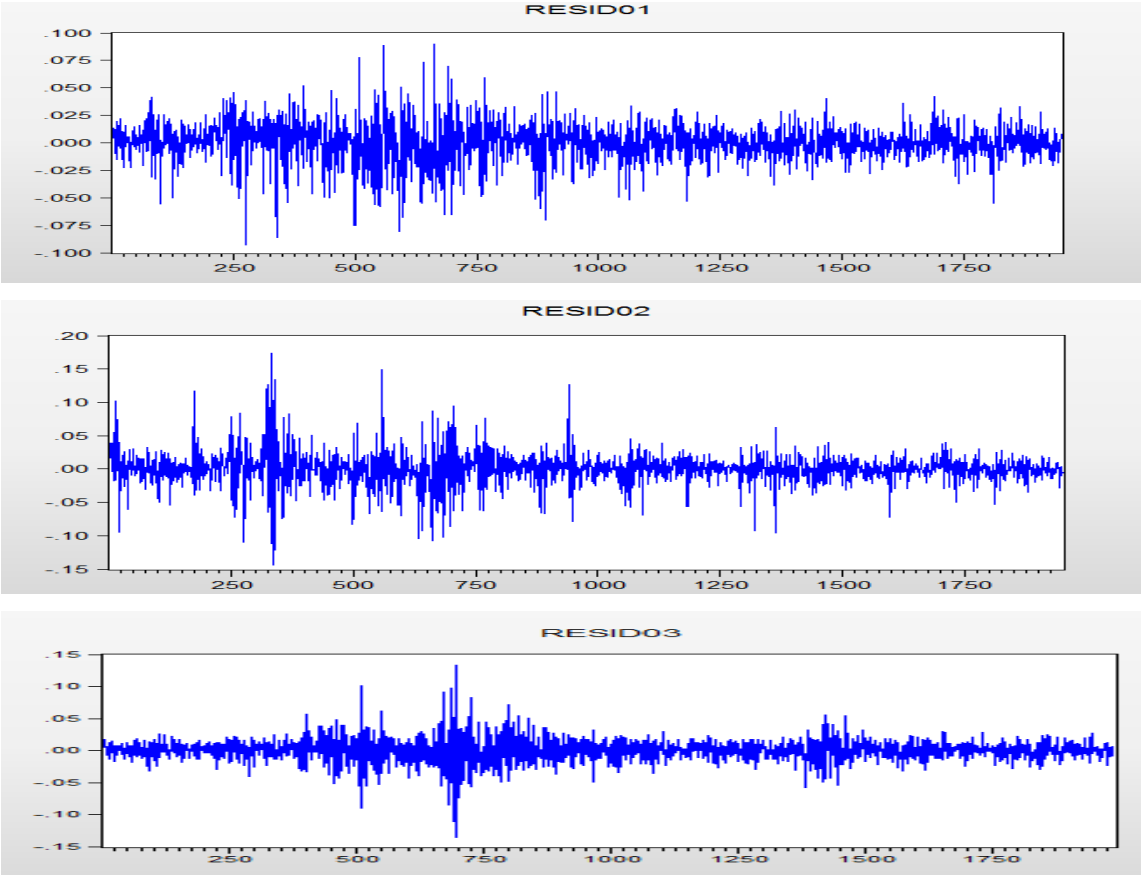



Figure. 3 correlation diagram of residual square of daily yield of Shanghai Stock Exchange A, B share Index and Hang Seng Index

**GARCH Family Model to Calculate Results.**

According to the analysis above, there is no autocorrelation between the logarithmic yield of Shanghai A-share index, Shanghai B-share index and Hang Seng index, so the return equation is set as the general mean regression equation.For the convenience of calculation and empirical test, we choose the GARCH(1，l)class model to establish the models of GARCH(1,1)、EGARCH(1,1)、PARCH(1,1) respectively. The models are as follows:

$$r_t = c_0 + \varepsilon_t \quad (1)$$

$$\varepsilon_t = \sqrt{\sigma_t^2} * z_t \tag{2}$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2 \tag{3}$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 \left| \frac{\varepsilon_{t-1}}{\sqrt{\sigma_{t-1}^2}} \right| + \gamma_1 \frac{\varepsilon_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \beta_1 \ln(\sigma_t^2) \tag{4}$$

$$(\sqrt{\sigma_t^2})^\delta = \alpha_0 + (\alpha_1 |\varepsilon_{t-1}| - \gamma_1 \varepsilon_{t-1})^\delta + \beta_1 \sqrt{\sigma_{t-1}^2} \tag{5}$$

$$\alpha_0 > 0,\ \delta \geq 1,\ \beta_1 \geq 0,\ \alpha_1 \geq 0,\ |\gamma_1| < 1$$

We assume $z_t$ as a sequence of independent and identical variables with a mean value of 0 and a variance of 1. When the distribution is a normal distribution, the calculated value of risk $VaR_t$ is $VaR_{t+1|t} = \hat{\mu} + F(\alpha)\widehat{\sigma_{t+1|t}}$

When the distribution is t-distribution of degree of freedom, the calculated value of VaR is adjusted to: $v$

$$VaR_{t+1|t} = \hat{\mu} + \sqrt{\frac{v-2}{v}} F(\alpha)\widehat{\sigma_{t+1|t}}$$

Among them $F(\alpha)$ is the corresponding quantiles of the discussed distribution ($\alpha$ is 5%, 1%, respectively). $\widehat{\sigma_{t+1|t}}$ is the basis

The information prior to the time t predicts the conditional variance value of the t+1 moment.

Calculation results of GARCH family model for each stock index

**Calculation results of GARCH Family Model of Shanghai Stock Exchange A-share Index.**

1) Parameter estimation under the assumption of normal distribution

| Model | $c_0$ | $\alpha_0$ | $\alpha_1$ | $\beta_1$ | $\gamma_1$ |
|---|---|---|---|---|---|
| GARCH(1,1) | 0.000228 | 2.05E-06 | 0.046929 | 0.946486 | |
| | (0.718300) | (3.747229*) | (8.355269*) | (148.4870*) | |
| EGARCH(1,1) | 0.000204 | -0.158306 | 0.114823 | -0.006012 | 0.991177 |
| | (0.640147)) | (-6.573671*) | (9.458913*) | (-1.092489) | (430.2147*) |
| PARCH(1,1) | 0.000210 | 3.64E-05 | 0.057800 | 0.040131 | 0.946415 |
| | (0.641709) | (0.763566) | (8.011646*) | (0.780787) | (150.7364*) |

From the parameter estimation of the model, the parameters of GARCH (1,1) and EGARCH (1,1) are significant at the 5% significant level.In particular, ARCH and GARCH tests were significant.While under the LM test of heteroscedasticity effect for estimating residual error there is no significant heteroscedasticity phenomenon any more. Therefore, the model GARCH(1,1)、

EGARCH(1,1))can better describe the phenomenon of logarithmic yield heteroscedasticity of A share index in Shanghai Stock Exchange.But the parameter test of PARCH(1,1)was not significant.

The following are the general statistical characteristics of each model's estimated VaR value, as well as the number of days of failure and the corresponding failure rate obtained by the return test method:

| Model | Confidence level (%) | Mean value | Standard deviation | Deviation degree | Kurtosis | Test interval | Failure days | Failure rate (%) | Reject the original hypothesis or not |
|---|---|---|---|---|---|---|---|---|---|
| GARCH(1,1) | 95 | -0.029 | 0.0125 | -0.823 | -0.209 | 600 | 32 | 5.33 | No |
| | 99 | -0.040 | 0.0177 | -0.823 | -0.209 | 600 | 15 | 2.5 | Yes |
| EGARCH(1,1) | 95 | -0.028 | 0.0125 | -0.891 | 0.0556 | 600 | 32 | 5.33 | No |
| | 99 | -0.040 | 0.0177 | -0.891 | 0.0556 | 600 | 17 | 2.83 | Yes |
| PARCH(1,1) | 95 | -0.028 | 0.0126 | -0.938 | 0.1047 | 600 | 31 | 5.17 | No |
| | 99 | -0.040 | 0.0179 | -0.938 | 0.1047 | 600 | 16 | 2.67 | Yes |

Under the confidence level 95%, from the prediction results of VaR, there is no significant difference in the VaR mean calculated by the three models. The estimated standard deviation EGARCH and the PARCH model are less than the general GARCH model.It is estimated that the number of failures is not obvious, and the failure rate is close to 5%.According to the LR statistics test proposed by Kupeie (1995), the original hypothesis can not be rejected at the 5% significant level, but once the confidence level is raised to 99%, according to the Kupeie (1995) test , the original hypothesis is rejected under the 1% significant level , so it can be concluded that the VaR prediction results calculated by the three models are not ideal for the A share index of the Shanghai Shanghai stock market.

2.Estimation of parameters under the assumption of the t-distribution

| Model | $c_0$ | $\alpha_0$ | $\alpha_1$ | $\beta_1$ | $\gamma_1$ | Degree of freedom |
|---|---|---|---|---|---|---|
| GARCH(1,1) | 0.000621 | 1.47E-06 | 0.042084 | 0.954733 | | 5.1853 |
| | (2.0739*) | (1.939035*) | (5.042485*) | (110.4733*) | | （7.2313*） |
| EGARCH(1,1) | 0.000611 | -0.122476 | 0.101782 | -0.002045 | 0.994175 | 5.2327 |
| | (2.0425*) | (-3.976758*) | (5.688725*) | (-0.234317) | (340.1118*) | （7.1643*） |
| PARCH(1,1) | 0.000627 | 7.16E-07 | 0.038588 | -0.027075 | 0.955879 | 5.1741 |
| | (2.0786*) | (0.339097) | (2.735611*) | (-0.378895) | (111.6811*) | （7.2369*）（ |

According to the estimation parameters of the model, the parameters of each model are all significant at the 5% confidence level, and the Lagrange multiplier test of the estimated residual will

find no significant heteroscedasticity, so the model above can describe the difference of the logarithmic return of the A share index of the Shanghai stock market.

The following are the number of days of failure and the corresponding failure rate for each model to estimate the VaR value by using the return check method:

| Model | Confidence level (%) | Mean value | Standard deviation | Deviation degree | Kurtosis | Test interval | Failure days | Failure rate (%) | Reject the original hypothesisor not |
|---|---|---|---|---|---|---|---|---|---|
| GARCH(1,1) | 95 | -0.027 | 0.0122 | -0.742 | -0.362 | 600 | 34 | 0.0567 | 否 No |
| | 99 | -0.046 | 0.0202 | -0.742 | -0.362 | 600 | 15 | 0.025 | 是 Yes |
| EGARCH(1,1) | 95 | -0.027 | 0.0122 | -0.823 | -0.114 | 600 | 35 | 0.0583 | 否 No |
| | 99 | -0.044 | 0.0202 | -0.823 | -0.114 | 600 | 15 | 0.025 | 是 Yes |
| PARCH(1,1) | 95 | -0.027 | 0.0120 | -0.687 | -0.465 | 600 | 34 | 0.0567 | 否 No |
| | 99 | -0.046 | 0.0200 | -0.687 | -0.465 | 600 | 13 | 0.0217 | 是 Yes |

As shown in the table, compared with the VaR prediction results of normal distribution, the prediction value of t-distribution is small at 95% confidence level, and the failure rate and the left tail probability is so high to underestimates the risk.When the left tail probability is smaller (1%), the failure rate is reduced, which indicates that the more accurate the A share index of the Shanghai stock market is at the back of the tail, the more accurate the VaR value measured by the thick tail distribution (t-distribution) is better than the normal distribution.

Using the same method, we can calculate the VaR/ of Shanghai B and Hang Seng index.

## Conclusion

From the general statistical information of logarithmic return rate of stock index, it can be concluded that both Shanghai Stock Exchange A, B share Index and Hang Seng Index have the characteristics of sharp peak and thick tail and obvious volatility aggregation. Through empirical analysis, it is suitable to establish GARCH-t model. The more backward of the tail it is, the more accurate the tail probability(t-distribution) is, and the higher the accuracy of the predicted VaR is, the better the EGARCH-t and PARCH-t are for the calculation of VaR.

From the calculation results of the model parameters, it can be concluded that the predicted values $\gamma$ of A and B share index of Shanghai Stock Exchange in China are all greater than zero, and the statistics are quite significant, that is, the positive information shock is greater than the negative information shock, which indicates that there is a leverage effect. It also proves that there is information asymmetry in Shanghai stock market, and the response of good news is stronger than that of bad news. It also shows that the market mechanism of China's stock market is not perfect. Therefore, we should further improve the information disclosure system of enterprise listing, perfect the legalization of securities market construction, and explore the impact of investors' psychological behavior on the stock market.$\gamma$

To sum up the prediction effect of the VaR value above, through the Back-test, the results show that both the Shanghai stock index and the Hongkong Hang Seng index can pass the validity test of the VaR under the given GARCH model, but the failure rate is slightly higher than 5% (or 1%), so there is the phenomenon of underestimating the risk. The undervaluation of VaR may cause investors' investment behavior to be too radical, which will cover up or delay the exposure of the risk of listed companies' operation, thus causing the volatility of the stock market to increase further.

Whether in normal distribution or t-distribution, the prediction effect of VaR on A-share index of Shanghai Stock Exchange is not ideal, and the failure rate is obviously higher than the probability of left tail, so the model should be improved.

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