Application of Monte Carlo Simulation Based on GARCH Model in Risk Measurement of Stock Market in China

Chang Cheng [a,*], Wenbin Bao [b]

Nanjing University of Science and Technology, Nanjing 210094, China

[a]731369655@qq.com, [b]1044024532@qq.com

*Corresponding author

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Abstract: VaR method is an effective financial market risk measurement tool. In this paper, we estimate conditional heteroscedasticity of return series based on GARCH model, aiming at the observed volatility clustering and the trailing peak and tail characteristics of return series in financial markets. On this basis, the full valuation Monte Carlo simulation method is used to simulate the change path of the Shanghai-Shenzhen 300 index and calculate its risk value. Finally, the simulation results are tested by return, which proves its validity.

1. Introduction

The frequent financial catastrophic events in the 1990s have been sounding alarms to us. Quantifying financial market risks has become an urgent problem to be solved. In this context, in 1993, the G30 Group first proposed VaR model to assess financial risk. In the same year, the Bank for International Settlements (BIS) accepted VaR analysis tools and was embodied in the Basel Capital Accord. In 1994, J. P. Morgan, a world-renowned consortium, fully applied the VaR method to measure financial risk. Since then, the VaR method has gradually become an international standard for risk management and has been continuously improved and developed. With the development of financial liberalization and financial globalization, financial risk management has increasingly become the basis and core of modern financial institutions.

The empirical analysis of VaR method in China mainly focuses on the improvement of variance-covariance method and historical simulation method by using different distribution hypothesis and conditional heteroscedasticity model to better apply to the characteristics of financial time series, while the empirical analysis of combining conditional heteroscedasticity model with full valuation Monte Carlo simulation method is rare. Based on the empirical analysis of the closing price data of Shanghai and Shenzhen 300 index, this paper proves the effectiveness of the Monte Carlo simulation method based on GARCH model in China's stock market risk measurement.

2. Models and methods

VAR is the maximum loss that a financial instrument or its portfolio will face under future asset price fluctuations at a certain confidence level and a certain holding period.

$$P\left(L > VaR\right) \le 1 - c$$

Among them, c is the confidence level and L is the potential loss.

There are many different ways to measure VaR. The variance-covariance method, because the income distribution of most financial assets presents the characteristics of thick tail, in this case, the model based on the assumption of normal distribution underestimates the real VaR value. The historical simulation method also has obvious drawbacks. It uses only one sample path and depends on a time window. It is difficult to balance the accuracy and stability in the actual application process. In contrast, Monte Carlo simulation is the most effective method to measure VaR so far.

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3. Empirical analysis

This paper selects the closing price of Shanghai and Shenzhen 300 Index from April 8, 2011 to May 20, 2015 for 1000 trading days as a sample, and the data are from Wind information. The logarithmic return series is generated from the original data.

$$R_t = \ln S_t - \ln S_{t-1}$$

Among them, R_t means the daily return of the Shanghai and Shenzhen 300 Index and S_t is the daily closing price.

3.1 Statistical Test of Return Rate Series

Eviews 7.0 is used to test the normality of the data. The histogram and descriptive statistics of logarithmic return series are obtained. Logarithmic return rate does not satisfy normal distribution, showing the characteristics of "peak and heavy tail"

From the logarithmic yield sequence diagram, we can know that the return rate fluctuates slightly around the mean value, and we can preliminarily judge that the sequence is stable. At the same time, it is observed that the time series of earnings show obvious aggregation effect.

Observing the autocorrelation graph of the return series R, we can see that there is no autocorrelation. Therefore, by directly regressing R pairs of constants, the residual square sequence obtained is obviously different from 0 at the second order of lag, that is, there is autocorrelation. The LM test (e.g. Table 2) was further carried out and the lag order was selected as 2.

The p value is approximately zero, that is to say, ARCH effect exists in the return series at any significant level. Therefore, the traditional use of standard deviation to measure the volatility of return rate can not reflect the concentration of volatility, which will weaken the prediction effect of VaR method. So we choose to establish GARCH model and replace standard deviation with conditional standard deviation.

The results show that the coefficients are significant, and there is no autocorrelation between the residual sequence and the residual square sequence. The p value of LM test is 0.1796 (Table 1), and there is no ARCH effect. Therefore, it is reasonable to establish a model.

Table 1 Arch effect test results

	ARCH(2)	GARCH(1,1)
F-statistic	14.3884	1.8004
Prob.	0.0000	0.1800
Obs*R-squared	28.0515	1.8007
Prob.	0.0000	0.1796

3.2 Calculating VaR Value by Monte Carlo Simulation Based on GARCH Model

Using 500 days as the time window, we use the 500 days yield data from April 11, 2011 to May 2, 2013.

(1) Calculate the mean μ and get the conditional variance h_t^2 of May 3, 2013 based on the estimated model $GRACH(1,1)$. If the holding period of one day is divided into 100 equal periods, the mean return $\frac{\mu}{100}$ and standard deviation of conditions $\frac{h_t}{10}$ for each period can be obtained.

(2) 100 random numbers which obey the normal distribution are generated, and the simulated price S_{t+1} at t + 1 time can be obtained by bringing S_t (the closing price on May 2, 2013), $\frac{\mu}{100}$, $\frac{h_t}{10}$, in $S_{t+1} = S_t + S_t\left(\mu\Delta t + \sigma\varepsilon\sqrt{\Delta t}\right)$. Similarly, we can get a simulated closing price $S_T^1 = S_{t+100}$ on the next trading day (May 3, 2013).

(3) Repeat steps (2) 1000 times to get 1000 possible simulated closing price series

$\left(S_T^1, S_T^2, \cdots, S_T^{1000}\right)$. If the simulated price is ranked and the confidence level c is selected, the result will be $VaR = S_t - S_T^{\min(1-c)}$ (May 3, 2013).

The VaR values of 498 trading days from May 6, 2013 to May 20, 2015 can be obtained by pushing back the time window 498 times and repeating the above steps (1), (2), (3).

Test the failure rate of the simulation results (Table 2). The calculated value of the LR statistic is 2.2473, which is less than the critical value of the 95% confidence interval of the χ^2 distribution of degree of freedom 1, which is 3.8415. Therefore, the original assumption that the receiving model is effective is that the Monte Carlo simulation method based on GARCH model can estimate the VaR value well.

Table 2 Failure rate test

k	Inspection days T	Failure Days N	Failure rate	LR	Chi-Square(1)
500	499	18	0.0361	2.2473	3.8415

4. Literature References

VaR calculation is essentially a statistical measurement of portfolio value fluctuations. Its core is to construct the probability distribution of portfolio value changes. The basic idea is still to use the historical volatility information of portfolio value to infer the future situation, but the inference of future value volatility gives not a definite value, but a probability distribution[1,2].

For a given returns series, the ranking of VaR forecast procedures depends on the period of time considered, the procedures compared and the measures used to compare them[3].

GARCH models always outperform stochastic volatility models when they are estimated using MCMC methods in four Asia-Pacific stock markets[4].

Based on the closing price data of Tongfang Co., Ltd., the VaR values are calculated by three methods, and the failure rate is tested and the advantages and disadvantages are compared. The results show that Monte Carlo simulation is the most suitable method[5].

5. Conclusion

The logarithmic return series of Shanghai and Shenzhen 300 indices exhibit peak and heavy tail. Therefore, the variance-covariance VaR method based on the assumption of normal distribution often underestimates the real VaR value. The Monte Carlo simulation method, which does not depend on the specific distribution, can effectively simulate the real price change path.

Based on Garch Monte Carlo simulation method, the risk value model using moving time window can be tested by the failure rate of empirical analysis, thus proving the validity of the model.

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