Financial Risk Quantification Research Based on Monte Carlo Simulation

Jingsong Wu

College of Finance, Central University of Finance and Economics, Beijing 102206

Keywords: VaR, Financial Risk Quantification, Monte Carlo Simulation

Abstract: With the continuous development of the financial industry, financial risk management has become more and more important. The method of using it to do scientific risk measurement has gradually become a hot research field. This paper is aimed at the financial industry's widely accepted risk quantitative analysis method VaR (Value at Risk) conducted related research. Firstly, the three main aspects of VaR application are analyzed, and the Monte Carlo simulation principle is elaborated. Secondly, the price of the index is the Monte Carlo model for the research data. Finally, the model is verified and the research results show that the model can effectively measure financial risks.

1. Introduction

With the increasing internationalization of global economic activities, the economic, political, and social environments in which microeconomic entities are located are becoming increasingly complex, and their operations are also facing increasingly diverse and increasing risks. This is particularly true in financial markets. The so-called financial risk refers to the possibility of losses caused by the financing and utilization caused by the uncertainty in economic activities. There are several types of financial risks: Market risk refers to the risk arising from fluctuations in the market price of financial assets or liabilities; credit risk refers to the risk arising from the non-performance of the contract or the inability to perform the contract; the operational risk refers to The risk of not being able to carry out the expected transaction; Liquidity risk refers to the risk arising from insufficient liquidity in financial markets or insufficient liquidity of financial traders.

VaR is suitable for a comprehensive measurement of various market risks including interest rate risk, exchange rate risk, stock risk, and commodity price risk and derivative financial instrument risk. Therefore, this allows financial institutions to use a specific indicator value (VaR) to generally reflect the risk status of the entire financial institution or portfolio, which greatly facilitates the exchange of relevant risk information among the business units of financial institutions, and facilitates the organization. The top management keeps abreast of the overall risk situation of the organization, which is very beneficial to the unified management of risks by financial institutions. At the same time, the regulatory authorities have also been able to impose uniform requirements on the market risk capital adequacy ratio of the financial institution.

2. VaR Application Analysis

2.1 Financial Supervision

Using VaR calculation results, the supervisory authority can more easily calculate the minimum capital reserve amount required for financial institutions to prevent market risks, and external credit rating agencies also have a quantitative basis for issuing credit ratings. The Basel Committee provides for its VaR risk in its Internal Model Law on Market Risk Capital Requirements (1995) and the Regulatory Framework for the Internal Model Method for Testing Market Risk Capital Requirements Using the Return Inspection Method. The risk calculated by the measurement model is used to determine the bank's capital, and feasible recommendations and clear provisions are made for the use of this measurement method and the testing of the model. Financial supervisory authorities in many countries use VaR technology to monitor the risks of banks and securities firms, using VaR as a yardstick and basis for measuring the uniformity of financial intermediaries' risk and the capital adequacy of regulatory agencies.

2.2 Risk Control

More than 1,000 banks, insurance companies, investment funds, pension funds and non-financial companies have adopted the VaR method as a means of risk management for financial derivatives. The VaR method is used to manage the working capital, formulate an investment strategy, and timely adjust the investment portfolio by assessing and measuring the risk value of the assets held to diversify and avoid risks, improve asset operation quality and operational efficiency. In the case of Morgan Stanley, the company uses a variety of risk aversion methods to manage its positions, including the diversification of risk exposure positions, the trading of securities and financial instrument positions, and a wide variety of financial derivatives (including swaps). The use of futures, options and forward transactions. The company manages market risks associated with trading activities throughout the company by transaction unit and product unit worldwide. Risk control with the VaR approach allows each trader or trading unit to know exactly how much financial risk they are conducting and to set a VaR limit for each trader or trading unit to prevent excessive speculation. Appearance. If strict VaR management is implemented, some of the major losses in financial transactions may be completely avoided.

In addition, the VaR approach is a powerful analytical tool for institutional investors to make investment decisions. Institutional investors apply the VaR method to measure the risk of investment objects in the investment process, compare the calculated risk with their ability to withstand risks, and determine the investment amount and investment strategy to reduce the blindness of investment, to minimize the losses caused by investment decisions. At present, in addition to being widely used by financial institutions, the VaR method has also begun to be adopted by some non-financial institutions, such as Siemens and IBM.

2.3 Performance Evaluation

In financial investment, high returns are always accompanied by high risks, and traders may take huge risks to chase huge profits. For the sake of sound business operations, the company must limit the possible excessive speculation by traders. Therefore, it is necessary to introduce performance evaluation indicators that take into account risk factors.

3. Monte Carlo Simulation

The Monte Carlo simulation method uses a stochastic process to simulate the development law of the real system, thus revealing the laws of the system. For example:

$$Y=f(X);\ X=(x1, x2,\cdots, xn)$$

X is a random variable obeying a certain probability distribution, and extracts a number of specific values for X, and substitutes it into the above formula to find the corresponding Y value, so that repeated simulations are enough times (several thousand or tens of thousands) to obtain A batch of data Y1, Y2, ..., Yn, which can be used to describe the distribution characteristics of Y. The Monte Carlo simulation method is an empirical method based on the law of large numbers. The more the number of experiments, the closer its average value is to the theoretical value.

The Monte Carlo simulation assumes that the price change of the portfolio is subject to the form of a stochastic process, which can be simulated by a computer to generate a number of possible price paths, and then the return distribution of the portfolio is constructed to estimate the risk value. Selecting the price stochastic process, the most commonly used model is Geometric Brownian Motion, the random walk model:

$$dS_t = \mu_t S_t d_t + \sigma_t S_t d_z$$

Where dz is a random variable, subject to a mean of 0, and the variance is d_t normal distribution, parameters and respectively represent the instantaneous drift rate and volatility, which all change with time, and in simple cases they can be made constant. In practical applications, the discretized form of the above formula is more convenient to calculate:

$$\Delta S_{t+1} = S_t(\mu_t \Delta t + \sigma_t \varepsilon_t \sqrt{\Delta t})$$

The current time is t, the expiration time is T, and n is the number of segments into which the analog path is divided. ε_t represents a standard normal random variable. The above formula can be expressed as:

$$S_{t+1} = S_t + S_t(\mu_t \Delta t + \sigma_t \varepsilon_t \sqrt{\Delta t})$$

At time t, given S_t and estimate the corresponding parameters μ_t with σ_t, ε_t, t=1, 2,...n, will ε_t substituting the above formula, get S_{t+1}, then estimate μ_{t+1} with σ_{t+1}, put them and ε_{t+1} substituting the above formula, get S_{t+2}, and so on, and finally get S_{t+n}. This process is repeated several times, and then the quantile is calculated according to the given confidence, and the VaR of the asset can be obtained.

4. Empirical Analysis

4.1 Model Establishment

The data used in the model establishment is from the 200-day Shanghai Composite Index from January 4 to November 6,2000. The general Monte Carlo simulation method is used to calculate the Shanghai Stock Exchange Index on the next trading day (November 7,2000). VaR, the selected holding period is one day, and the confidence level is 95%.Here, we choose geometric Brownian motion as a stochastic model reflecting the change of the Shanghai Stock Index. The discrete form can be expressed as:

$$\Delta S_{t+1} = S_t(\mu \Delta t + \sigma \varepsilon \sqrt{\Delta t})$$

The general Monte Carlo simulation method uses the standard deviation to measure the volatility of the yield under the assumption of normal distribution. σ indicates the standard deviation of the yield of the Shanghai Composite Index, ε to be a random variable subject to the standard normal distribution. Here, we divide the holding period of the day into 20 equal time periods. S_t for the initial time of the Shanghai Composite Index, S_{t+i} for the Shanghai Composite Index at t+i time, ΔS_{t+i} representing the change in the Shanghai Composite Index in each time period, and the mean and standard deviation of the Shanghai Stock Index's return rate in each time period are $\frac{\mu}{\sqrt{20}}$ with $\frac{\sigma}{\sqrt{20}}$ the Shanghai Composite Index at t+i is:

$$S_{t+i} = S_{t+i-1} + \Delta S_{t+i}$$

$$= S_{t+i-1} + S_{t+i-1}\left(\frac{\mu}{\sqrt{20}}\Delta t + \frac{\sigma}{\sqrt{20}}\varepsilon_i \sqrt{\Delta t}\right)$$

The following is a detailed procedure for calculating the Shanghai Composite Index VaR on November 7, 2000 using the general Monte Carlo simulation method:

(1) Estimate mean and standard deviation:

Estimate the average of the 200-day Shanghai Stock Exchange Index from January 4,2000 to November 6,2000 μ and standard deviation σ and calculate the average return rate of the Shanghai Stock Exchange in each time period $\frac{\mu}{20}$ and standard deviation $\frac{\sigma}{\sqrt{20}}$;

(2) Generate random numbers:

Generate 20 random numbers subject to the standard normal distribution $\varepsilon_1, \varepsilon_2, ...\varepsilon_{20}$;

(3) Simulate a possible path for the price change of the Shanghai Stock Exchange:

Separately S_t (Shangzheng closing index on November 6,2000), $\frac{\mu}{20}$, $\frac{\sigma}{\sqrt{20}}$ with ε_1 substituting into the formula, you can get the Shanghai Stock Index at t+l time:

$$S_{t+1} = S_t + S_t(\frac{\mu}{20}\Delta t + \frac{\sigma}{\sqrt{20}}\varepsilon_1\sqrt{\Delta t})$$

By analogy, we can get:

$$S_{t+2} = S_{t+1} + S_{t+1}(\frac{\mu}{20}\Delta t + \frac{\sigma}{\sqrt{20}}\varepsilon_2\sqrt{\Delta t})$$

$$S_{t+3} = S_{t+2} + S_{t+2}(\frac{\mu}{20}\Delta t + \frac{\sigma}{\sqrt{20}}\varepsilon_3\sqrt{\Delta t})$$

$$\vdots$$

$$S_{t+20} = S_{t+19} + S_{t+19}(\frac{\mu}{20}\Delta t + \frac{\sigma}{\sqrt{20}}\varepsilon_{20}\sqrt{\Delta t}) = S_T$$

Among them $S_{t+1}, S_{t+2}, \ldots S_{t+20}$ is a possible path for the price change of the Shanghai Composite Index, S_T is a possible closing price of the Shanghai Composite Index on November 7,2000.

Repeat steps 2 and 3, 10,000 times, and get 10,000 possible closing prices of the Shanghai Composite Index. $S_T^1, S_T^2, \ldots, S_T^{10000}$;

(4) Calculate VaR:

Correct $S_T^1, S_T^2, \ldots, S_T^{10000}$ sort in order from small to large, find the 5% quantile below $S_T^{\min 5\%}$, we can calculate the VaR at 95% confidence level:

$$VaR = S_t - S_T^{\min 5\%}$$

Finally, the VaR of the Shanghai Composite Index for the next trading day (November 7,2000) was calculated to be 46.14.

4.2 Empirical Analysis

This article is based on the closing price of Shenzhen Shenjin Development (stock code: 000001) and Shanghai Qilu Petrochemical (stock code 600002) on March 1, 2006 (Shenzhen Development 6.78 yuan, Qilu Petrochemical 10.05 yuan), respectively, calculating the daily and weekly prices of the two stocks. VaR for the month, week and month of the month VaR and their combination. Only one VaR is calculated for a single asset, and one share for each asset portfolio. The weights in the portfolio are: 40.29% for SDB and 59.71% for Qilu Petrochemical. Assuming that the correlation coefficient of two stocks in the portfolio is 0, the VaR of the portfolio can be calculated by weighted average.

Table.1. Stocks and their combinations VaR

Assets	Confidence	Day VaR	Week VaR	Month VaR
Deep Development	90%	0.1601	0.1832	0.2042
	95%	0.2079	0.2180	0.2446
	99%	0.3341	0.3382	0.3401
Qilu Petrochemical	90%	0.2632	0.2711	0.3089
	95%	0.3524	0.3800	0.3876
	99%	0.6257	0.6321	0.6536
Assets Combination	90%	0.2217	0.2357	0.2668
	95%	0.2942	0.3147	0.3300
	99%	0.5082	0.5137	0.5273

Table 1 shows the VaR values calculated by the Monte Carlo simulation method. It can be seen from the data in the table that the higher the confidence level of the same stock, the higher the VaR value; the longer the holding period, the longer the VaR value of the same stock; The VaR value of the stock portfolio is less than the sum of the individual VaR values of the two stocks, which further illustrates the correctness of the investment strategy of “Don't put the eggs in the same basket”. When calculating the VaR value of the stock portfolio, it is assumed that the two stocks are irrelevant, so the simple weighted average method can be used. In the actual economic activities, many assets are related, and this should be taken into consideration in practical applications.

5. Conclusion

VaR can generally reflect the risk status of the entire financial institution or portfolio, which greatly facilitates the exchange of relevant risk information among the financial institutions, and facilitates the top management of the organization to keep track of the overall risk status of the organization, but because of the VaR data. Strict requirements, this risk measurement method is more effective for transactions, and the risk measure of financial instruments that are easy to obtain at market prices is more significant, while for assets lacking liquidity, such as bank loans, due to the lack of daily market transaction price data, The ability to measure risk is greatly limited. Sometimes, it is necessary to break down a financial product with poor liquidity into a combination of highly liquid financial products, and then use the VaR model to analyze its risk.

References

[1] Zhao Rui, Zhao Ling. VaR Method and Portfolio Analysis [J]. Quantitative Economics and Economics Research. 2002 (l1): 44-47.

[2] Jing Naiquan, Chen Wei. Var model and its application in portfolio [J]. Finance and Trade Economics. 2003 (2): 68-71.

[3] Yao Xiaoyi, Teng Hongwei, Chen Chao. Scale risk control of asset management business of securities companies [J]. Economics. 2002 (5): 65-67.

[4] Ying Dingwen. Index Futures and Securities Institutions Quantitative Risk Management System [J]. Quantitative Economics and Technology Economics Research. 2002 (10): 71-74.

[5] Du Haitao. Application of VaR model in securities risk management [J]. Securities Market Herald. 2000 (8): 57-61.

[6] Jorion P. Value at Risk: The New Benchmark for Controlling Market Risk [M]. McGraw-Hill, New York, 1997.