Proceedings of the 3rd International Conference on Business and Policy Studies
DOI: 10.54254/2754-1169/81/20241530

Stock Price Volatility Prediction Based on GARCH and Related Models

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Abstract: In the modern financial industry, the stock market is favored by most financial investors. Because of its high risk and high return, many people in society are willing to invest a lot of money in the stock industry to seek huge profits. Many factors affect the stock price trend, and a stock price has volatility and activity in the constantly fluctuating stock market. For the financial market, the appropriate volatility of stock prices is conducive to the stable development and safety of the financial market. Still, when unexpected risks appear, it may lead to drastic changes in stock prices. From the investor's point of view, the return on investment is always accompanied by risk, and how to predict the risk affecting the stock price fluctuation is the key to whether investors can make profits from stock investment. In this article, it will start with GARCH and review how other scholars use the GARCH model to predict the risk of stocks or other financial instruments.

Keywords: GARCH model, Risk prediction, Stock price.

1. Introduction

Stock is a component of the capital of a joint stock company, which can be transferred and traded and is the main long-term credit tool in the capital market. Investors buy stocks not for the company's ownership but more for the purpose of making profits through the exchange of stock ownership. In the financial market of countries, the stock market undoubtedly makes a rapidly developing market. Countless people invest in the stock market to seek the maximum benefits. Still, the income of stock is often accompanied by risk, so it is necessary for financial researchers to analyze and consider the trend and risk of stock. The circulation of stock in the secondary market is the manifestation of the development and activity of the stock market.

At the same time, it also reflects the changes in the financial market and economic development in countries. Changes in the stock market will bring about a certain range of fluctuations in stock prices. Such volatility ensures the activity and development of the stock market in countries' financial market. As a relatively new financial market in countries, the stock market has developed rapidly in recent years, attracting many investors and promoting the sustainable development of related industries.

Moreover, as a relatively young market, the market supervision system and other aspects of the stock market have not been effectively improved. In some extreme cases, the stock market is prone to large fluctuations, resulting in large changes in stock prices. Whether the prediction of stock price fluctuation is accurate or not has always been the concern of investors and related investment

DOI: 10.54254/2754-1169/81/20241530

companies. The prediction of stock price volatility is also an estimate of the risks it may encounter in the future. For investors, predicting stock future risks can reduce the losses they may encounter in the process of stock investment and reduce the scale of losses as much as possible. For the financial investment market, the accurate prediction of stock price volatility and future risks can make the environment of the financial investment market more stable and create a more stable financial investment market order. Stock price fluctuations under risk factors must be predicted in time to prevent excessive losses, so a more accurate model is needed to achieve this goal. The GARCH model can fit the volatility problem in time series more accurately to achieve the experimental purpose of simulation and prediction. Therefore, this paper chooses the GARCH model to study the volatility of stock price and thus deduces the prediction of its future risk.

2. Literature review

2.1. Researches on the ARIMA model

The ARIMA model, also known as the autoregressive moving average model, is applied to time series algorithms, first proposed by statisticians in the United Kingdom and the United States in the 1970s. It combines the autoregressive model with the moving average model to obtain a new model capable of time series prediction. For different objects, ARIMA models with different parameters are often used to predict, and a model more suitable for a period of data is found through the partial correlation coefficient and the tailing or truncation of the correlation coefficient of the time series. The modeling steps usually include the stabilization of the sequence, the order determination of the model, and the parameter estimation. Although the ARIMA model does not meet most predictions, it is still highly practical in a certain range. Therefore, many researchers also use ARIMA to study the data suitable for the model to get more accurate predictions than other models.

In Lisha's paper, the ARIMA short-term price prediction model was used to evaluate the factors affecting the vertical and horizontal fluctuations of vegetable prices under the special background of the novel coronavirus pneumonia epidemic. Finally, based on the factors affecting vegetable prices, the model's results are tested [1]. And put forward constructive suggestions. Perim's paper uses the ARIMA model to conduct a time series study on specific diseases. Through information fitting, it can find the difference in information caused by underreporting and finally give the appropriate conclusion [2]. In A A,F E,H A's paper, the time series analysis and related processing of life expectancy at birth were carried out. The ARIMA model was selected as the model used in the prediction to make the fitting prediction of the data, and the conclusion of basic fitting was drawn at the end of the paper [3]. Moreover, the ARIMA model was used to predict the relationship between the total number of COVID-19 confirmed cases and the total number of discharged cases in S. A,P. N,O. O's paper and autocorrelation coefficient and partial autocorrelation coefficient were used to construct the model, and constructive suggestions were given based on the final results [4]. Lin Z,Kuang J,Li W used various models to process the collected temperature data and finally found that the ARIMA model was the best. Through the construction of the time series, the short-term prediction results of the ARIMA model could be obtained, and the analysis conclusion was finally drawn [5]. Lastly, by using the mixed model of the time series function to detect the ARIMA model, Oksana can finally verify the feasibility of the method used in his research field by using the ARIMA model to detect the time series [6].

2.2. Researches on the GARCH model

Most of the above studies using the ARIMA model can obtain relatively accurate prediction results, but there are also a few inaccurate predictions due to excessive errors. This is because the fluctuations in the time series in the ARIMA model are interfered with by a variety of factors, which are usually

DOI: 10.54254/2754-1169/81/20241530

not in the form of constants. Therefore, a special model is needed to rationally express the experimental changes in stock prices over time series. Therefore, the GARCH model, as an extension of the ARCH model, can be used to describe many complex properties and can be combined with many other models to improve the accuracy of prediction. The GARCH model is a kind of model that can predict data estimate risks and even guide investors' behavior. Therefore, many researchers have studied the GARCH model as follows:

In Lithin's paper, the author uses the GARCH model to predict the volatility of bond yield with empirical evidence. Through market decomposition, the author can classify the market for research, get enlightenment on volatility, and finally get advice on financial investors [7]. In Huaping's paper, the author conducted in-depth development and research on the GARCH model, enhanced the accuracy of the GARCH model for specific object simulation from different angles, and finally successfully developed a GARCH model that can simulate specific bounded time series and successfully analyze it. This study recommends that shareholders, investors, and policy participants in the Nigerian stock exchange market should be well prepared in the form of diversification of equity investments to withstand possible future market crises [8]. In Zouheir's paper, nine versions of the GARCH model were used to predict and analyze the impact of COVID-19 on multiple stocks. By obtaining data and constructing multiple GARCH models, the author could finally obtain the correlation analysis of COVID-19 on multiple stocks and the results and investment suggestions [9]. The GARCH model makes more accurate volatility prediction in Samreen's paper when dynamic conditions are relevant. After testing, the results of the mixed model's volatility test on samples can be compared, and it is finally confirmed that the mixed model is more suitable for modeling and forecasting the stock price index under consideration [10]. Moreover, Marwan's paper analyzes the performance of the ARCH model in a variety of time series applications. It gets a new strategy that can be used more effectively for research behavior [11]. In Donggyu's paper, the author further refined the estimation process of the GARCH model to obtain more accurate research results and tested the sample performance through simulation research. The author proposed a new estimation method based on the GARCH model to obtain more accurate conclusions and the comparison results of various assets obtained by this method [12].

2.3. Researches of GARCH model-related combination model

It can be seen from the results of the research paper in the above paragraph that the GARCH model can effectively perform some data estimation. Still, GARCH has a more accurate expression for data estimation, and such a more accurate prediction requires a combination of models. ARMA-GARCH and ARMI-GARCH models are widely used, which is also why the ARIMA model was introduced in the previous part. By combining models, more accurate prediction results can be obtained. Therefore, some studies of ARMA-GARCH and the ARMI-GARCH model will be introduced later.

Siroos uses the ARMA-GARCH model to build a model, puts forward his own brief introduction to a variety of different research directions in time series, and then introduces the copula ARMA-GARCH model to study the case, and finally gets the data and conclusions [13]. In Rubin's paper, the author introduces the correlation analysis of the GARCH model through the introduction of the algorithm and proposes a new algorithm to achieve the estimation and operation of the GARCH correlation model and effectively obtain the prediction results [14]. Chao L makes a more accurate prediction through the transformation and optimization of GARCH's extended model. The new GARCH-MIDAS-ES model can provide more accurate forecasts in various projects, such as weather forecasting [15]. Through the discussion and fitting of the GARCH model and related models, Yang can finally reach a conclusion on the correlation between stock crash and people's buying psychology. By comparison, more accurate prediction results can be obtained [16]. Adubisi proposed a new distribution mode and combined it with the GARCH model for more accurate modeling. At the same

DOI: 10.54254/2754-1169/81/20241530

time, several new indicators were introduced to predict the model. Combining the new distribution and GARCH model can obtain a more innovative structure to assist decision-making [17]. Yuanbo proposes a new GARCH model through the time series analysis and obtains the relevant model and theory applicable to American government bonds. The model can be applied to various time series with different properties. This GARCH combination model includes GARCH-type factors, which can process the data more properly [18].

2.4. Researches of VaR use

Similarly, as another combination of the GARCH model, GARCH-VAR is also commonly used for risk prediction. As a risk indicator, VaR can more accurately describe the prediction results in risk analysis problems. VaR refers to the maximum possible loss at a certain degree of trust within a specific period of time. It can be used as a financial indicator in various financial issues and to predict future risks and volatility. Taras made a systematic explanation of VaR, used VaR to discuss the solution of portfolio problems, and obtained the correlation between VAR and CVaR to assist in mathematical calculation. This paper analyzed the use of VAR and the conditions and effects of its use from a quantitative perspective [19]. Silvia's paper compares the advantages and disadvantages of multiple financial indicators by introducing new risk indicators. It uses multiple financial indicators, including VaR, to forecast financial risks and can obtain comparative results and advantages [20]. In Rui's paper, the constraints and limitations of VaR are discussed in a portfolio model, and some shortcomings of VaR are found in the portfolio model, which has significance for optimizing the model and modifying parameters [21]. Taylor James W estimates the data through the joint model of VaR and ES, and through the calculation of ES and VaR, it can be found that the dynamic of the two is the same, and a factor is obtained from them. After this, the two can be divided into a number formula composed of factors to carry out mathematical analysis and apply in the example [22]. In Liu's paper, VaR is used to calculate and predict the uncertain random variables that may appear in the prediction process, and the risk value is represented by the expectation of the probability distribution function. The resulting value-at-risk model can provide a more accurate answer to the portfolio question [23]. In Haddad's paper, the author discusses VaR by introducing a securities market mechanism. In discussing the use and algorithm of the circuit breaker mechanism, the selection of the model and the calculation method of VaR have also become one of the research objectives. The student-t distribution is estimated using the new GARCH extended model, and the accuracy of VaR is finally obtained. In this paper, the author uses quantitative analysis of enterprise strategy to get the deep learning algorithm and evaluates the prediction accuracy of the deep learning model from various analysis [24]. This analysis also has a reference for the prediction of the GARCH model above, and similar methods can be used to forecast and analyze the impact of price and volatility.

2.5. Researches of deep learning

As a very important research topic in recent years, deep learning has also been used in the research of financial markets. Deep learning methods also help to strengthen stock price prediction techniques in financial markets, and deep learning research can also help the ARMA-GARCH model to achieve future prediction. In traditional machine learning, the structure of the algorithm is mostly full of logic, which can be analyzed by people and eventually abstracted into some kind of flow chart or an algebraic formula, but deep learning uses neural networks to fit the input information many times, and the output value is constantly approximated to the real value through the superposition of functions. Deep learning is to fit algorithms and functions through machine learning and mathematical methods and finally apply the logic learned to new data, which is of great significance

DOI: 10.54254/2754-1169/81/20241530

for calculating the GARCH model and other models mentioned above and can make data predictions more accurately.

In Cheng's paper, the author analyzes the risk control aspects of the futures hedging strategy and proposes the analysis of a new algorithm based on deep learning. After repeated training, deep learning can obtain more suitable functions, and after combining various algorithms, the hedging efficiency can be improved, and the operating risk can be reduced [25]. Lingyan's paper also uses a deep learning model to conduct research based on some problems arising from data processing and use. For complex data, the accuracy of prediction is improved through data preprocessing and specific analysis. The simulation experiment is used to compare and select the model, and finally get the model more suitable for the data and get the predicted result [26]. In Muthukumaran's paper, the author analyzes the data of small and medium-sized enterprises to build a model, selects appropriate data classification methods to create appropriate data sets for data pre-processing, and then uses a variety of different deep learning technologies to analyze and predict the data, and carries out phased analysis and comparison of the proposed new technologies. And finally, develop a more suitable and excellent technology [27]. The importance of deep learning in risk management is mentioned in Guiling's paper [28]. In Li's paper, a machine learning model is established for international investment and risk of international projects, and an excellent model with the highest accuracy is finally obtained through the joint use and evaluation of multiple models [29]. In Fang's paper, the author conducts risk detection through the possible risks encountered in the development process of high-tech companies, properly processes and classifies the obtained data through the construction of a new framework and the proposal of a model, and then makes comparison and test to get the final result, and then analyzes the importance of various aspects and the test results of relevant data. Such data processing can also play a role in the processing and prediction of the GARCH model in this paper, and more accurate prediction results can be obtained through data processing [30].

3. The comparison and analysis of ARCH, GARCH, and GARCH combination models

This chapter will compare the difference between the ARCH model and GARCH model and introduce how to analyze the GARCH model and predict the future change trend. Firstly, the ARCH and GARCH models are compared and analyzed.

3.1. ARCH model

The AR(p) model is

$$x_t = \emptyset_0 + \emptyset_1 x_{t-1} + \cdots + \emptyset_p x_{t-p} + \varepsilon_t \ldots \quad (1)$$

and in the ARCH (q) model,

$$\varepsilon_t = \sigma_t \mu_t \ldots \quad (2)$$

$$\sigma_t^2 = a_0 + a_1 \varepsilon_{t-1}^2 + \cdots + a_q \varepsilon_{t-q}^2 \ldots \quad (3)$$

where μ_t is a random variable with a mean of 0 and a variance of 1.

For AR(p) models,

$$E(\varepsilon_t | F^{t-1}) = \sigma_t E(\mu_t | F^{t-1}) = 0 \ldots \quad (4)$$

$$D(\varepsilon_t | F^{t-1}) = \sigma_t^2 \ldots \quad (5)$$

When the AR(q) model is studied, the order q should be judged according to whether the sequence has a clear ARCH effect and then estimated by OLS and other methods. The analysis goal of ARCH

DOI: 10.54254/2754-1169/81/20241530

model is mainly to analyze the random fluctuation items in the model, and to explore whether there is ARCH effect through the variance analysis of the residual error, and finally to improve the accuracy of prediction.

3.2. GARCH model

GARCH model

$$\varepsilon_t = \sigma_t \mu_t \ldots \quad (6)$$

$$\sigma_t^2 = a_0 + \sum_{i=1}^{p} a_i \, \varepsilon_{t-i}^2 + \sum_{j=1}^{p} b_j \, \sigma_{t-j}^2 \ldots \quad (7)$$

of the μ_t is the mean to 0, the variance of 1 random variables. The p and q values in the GARCH model will affect the volatility of the forecast and produce a variance model that can describe the change of stock prices over time. GARCH model can play a great role in the prediction of volatility, but it also needs to rely on the modeling ideas such as ARMA model. GARCH model can be regarded as an extension of the ARCH model, which can be transformed into an ARCH model of infinite order under certain conditions, and has higher applicability.

4. Use GARCH model to forecast stock risk

After reading the above literature, one gets a more efficient and accurate method to predict the future risks of stocks, and the key is to use GARCH-VaR model to forecast the risks of stocks. First of all, descriptive statistics should be carried out on the collected data, and the time series of the rate of return can be obtained by recording the data statistics and related values one by one. After obtaining the sequence, the stationarity analysis is carried out, which is to eliminate the interference caused by the stationarity. By comparing the ADF test values, it can be found whether the time series is stable. If it is stable, it is ADF&lt. At 0.05, the analysis steps can be carried out. In the analysis process, the ARCH effect should be tested first, and the F statistic of regression can be obtained by calculating the sample mean and least square estimated residual, and the GARCH model can be used to test the influence of the effect. If you decide to use the GARCH model, you need to fit the parameters, calculate the t statistic of the parameters and other relevant parameters, and constantly adjust the parameters of the GARCH model to obtain a more appropriate model. Finally, using VaR for estimation, VaR will give a confidence interval within a certain range and get the maximum possible loss within the confidence interval. After placing the GARCH model, VaR values with different confidence levels can be obtained.

5. Conclusion

From the mathematical analysis of GARCH and ARMA models to the practical application. Many researchers have carried out a series of explorations on this, and with the help of related knowledge, they have achieved results in many fields. In the stock volatility and risk forecast discussed in this paper, ideal results can be obtained. In the previous literature review on multiple aspects of the GARCH model, it can be seen that the GARCH model and some related combination models are of great significance in the calculation and selection of financial products such as financial derivatives and stocks. The GARCH model can predict the future price fluctuations of stocks and define and forecast the risks of stocks with the help of VaR. With the rapid development of emerging technologies such as artificial intelligence, methods such as deep learning have also greatly improved the accuracy of prediction and can eventually adjust related financial operations through accurate results to obtain greater financial benefits. To sum up, the GARCH model and the development of related models are significant in studying world finance. In future research, researchers should pay

DOI: 10.54254/2754-1169/81/20241530

more attention to the combination of various models to deepen their research direction, and be able to achieve more accurate and realistic analysis and prediction.

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