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Risk Assessment of Listed Company Stock Investment Based on ARMA-GARCH Model and Monte Carlo Simulation

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Abstract. Under the dual backdrop of global economic integration and the digital transformation of financial markets, the European capital market, as a crucial global financial hub, has seen an increasing level of attention from investors, financial institutions, and regulatory authorities regarding the stock price fluctuations and risk characteristics of its listed companies. And this research subject SAP, as a listed company on Frankfurt Stock Exchange in Germany, engages in enterprise management software and cloud service businesses, which represents a blue-chip stock in the European technology sector. Hence, there stock price is not only to stand for company's own operating condition, but also reflects the influence of European technology industry, capital market liquidity, and the macro environment. Meanwhile, the stock price sequence of SAP Company exhibits typical characteristics of financial time series: clustered fluctuations, sharp peak and heavy tail, which are suitable for quantitative modeling. Therefore, this is a typical research subject of exploring the value of time series in stock prices. Moreover, with the advancement of technology, quantitative finance has experienced rapid growth. Various models and AI algorithms can be used to simulate events in multiple fields, such as option pricing, stock price simulation, and daily trading. This research has successfully established a precise model for stock returns and volatility, while enabling reproducible simulations of future price trajectories and delivering quantitatively accurate stock price forecasts. This model demonstrates strong applicability for short-term stock price forecasting, and this quantitative prediction approach is built upon rigorous academic rationale and practical feasibility. Free from subjective judgments and empirical assumptions, it ensures fully reproducible and verifiable prediction outcomes.

Keywords: Stock Prediction, ARMA Mean Model, GARCH (1,1) Model, Monte Carlo Simulation, R language

1. Introduction

Currently, Domestic and foreign scholars have established a mature system for stock price prediction and volatility modeling. I intend to carry out some attempts to implement innovative methods based on their existing research. Hence, I want to attempt a single company prediction to see if this method can effectively predict the stock trend. This research will use the ARMA model to capture the autocorrelation structure of the yield sequence, the GARCH model to depict the volatility clustering

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of financial sequences, Monte Carlo simulation to generate random yields with the mean and volatility, and iterative calculation of future stock prices. This article focuses on the listed company SAP as the research subject by taking ARMA Mean Model to fit the mean of return, GARCH (1,1) Volatility Model to forecast volability and combining with Monte Carlo simulation to generate random numbers for probabilistic forecasting of stock prices over the next 30 trading days. This research set 10000 times randomly simulated paths, obtaining the median forecast, the 5% downside risk bound, and the 95% upward bound to achieve quantitative valuation and risk management. This research through simulating stock price predictions, can better provide the information to investors with reference significance regarding maximum drawdown and position control, which achieves the maximization of returns and risk avoidance, as well as provide reference value for researchers in the same field but with different research directions.

2. Theoretical basis

2.1. Stock definition

A stock is a certificate of ownership of a company, representing a partial ownership of the company's assets, earnings and decision-making power by the shareholders. In the stock investment market, the primary market refers to the equity investment made by entrepreneurs, industry investors, and financial investors in unlisted companies; the secondary market is where various investors buy and sell the stocks of listed companies after they go public; and there is also an "intermediate primary market", which refers to the strategic placement and targeted additional issuance of shares by listed companies to specific investors [1].

2.2. ARMA mean model

$$r_t = \mu + \sum_{i=1}^{p} \emptyset_i r_{t-j} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t \tag{1}$$

· r_t : logarithmic return at time t
· p, q : order of AR and MA terms
· $\emptyset_i \theta_j$: model coefficients
· ε_t : residual term

By using the ARMA model to fit the stationary time series problem, which achieves a better fitting effect and has relatively wide application value in the financial field [2].

In this study, we will define the disclosure as ARMA(1,1).

$$y_t = c + \emptyset_1 y_{t-1} + \varepsilon_t + \theta_1 \varepsilon_{t-1} \tag{2}$$

First of all, the ARMA(1,1) model performs similarly in terms of data fitting accuracy under similar conditions, and can get a simpler structure compared with the AR model or MR model. This conciseness enhances the interpretability and stability of the model because it reduces the number of parameters and complexity of the model.

Secondly, as a specific form of the autoregressive moving average model (ARMA), ARMA (1,1) inherits the characteristics of the ARMA model, such as wide applicability and small prediction error. It can effectively indicate the short-term fluctuations and long-term trends in the data sequence, combining with the two methods of autoregression and moving average, which have good prediction performance and interpretative ability.

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Thirdly, the ARMA (1,1) model can more flexibly capture the complicated autocorrelation structures in time series data because it combines the characteristics of AR and MA. Hence, this model can flexibly handle the autocorrelation and partial autocorrelation functions.

2.3. GARCH(1,1) model

Applying the standard GARCH (1,1) model to capture the characteristics of volatility clustering.

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

σ_t^2 : Conditional Variance
$\omega>0$, $\alpha_1 \geq 0$, $\beta_1 \geq 0$, $\alpha_1+\beta_1<1$
α_1 : ARCH coefficient
β_1 : GARCH coefficient

The GARCH (1,1) model can effectively indicate the "peak and heavy-tailed" phenomenon in the stock market [3,4].

Moreover, GARCH (1,1) only requires two parameters (α and β) to demonstrate the dynamics of conditional variance. Compared to the higher-order GARCH (p,q) model, GARCH (1,1) has fewer parameters, a simpler model structure, which is easier to estimate and interpret. At the same time, it performs well in the volatility modeling of many financial time series and can provide relatively accurate predictions of future volatility.

2.4. Monte carlo simulation principle

The Monte Carlo Simulation is based on probability statistics theory, which is a numerical calculation approach by using a large number of random samplings to obtain approximate solutions to the problem. Its core idea is to link complicated problem with probability model and utilize computers to implement more random experiments, using statistical results to approximate the true solution [5].

Random returns are generated based on the mean and volatility to iteratively compute future prices:

$$S_t = S_{t-1} \exp(\mu + \sigma Z_t),\ Z_t \sim N(0,1) \tag{4}$$

where Z_t is a standard normal random variable.

2.5. Distribution assumption

The rate of financial return commonly have the sharp peak, heavy tailed, non-normal characteristics, as well as the probability of extremely volatile higher than normal distribution consumption. Therefore, the student's t-distribution can control tail thickness by taking freedom parameter, leading to fitting the thick-tail phenomenon exactly.

The model uses Student's t-distribution to fit the fat-tailed feature of financial returns [6].

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3. Empirical design

3.1. Parameter settings

For Parameter settings, our experiment simulates 10000 times and uses random seeds:123456, the time duration of trading was 30 days, and the three different color lines (Blue, Red, and Green) will be present in the photo, which represent the median forecast, 5% extrme downside risk and 95% upside bound. For the Blue solid line of median forecast, this represents the central point of the benchmark probability of market evaluation within the parameter setting in the model. For the Red dashed line of 5% extreme downside risk, this is a situation that, in extreme market shocks, the figure can be used as a reference for the value in the risk, which indicates the maximum price decline that investors could afford in the short term. And lastly, the Green dashed line of 95% uoside bound reflected the space of potential profit by driving the positive market sentiment.

3.2. Data sources

For this experiment, the Sample Interval from 1st Jan,2021 to 3rd Mar,2026, and the date type is daily closing price, as well as the data source can be drawn back to Yahoo Finance. In this experiment process will utilize the Logarithmic Return Rate, which can eliminate heteroscedasticity and dimensionality effects.

4. Empirical analysis

4.1. Implementation process in R language

Using R studio, this research made a price trend prediction for SAP stocks over the next 30 days, which resulted in the median, the upward potential range, and the downward potential range.

```
# ==============================================================
# SAP 30 days prediction
# ==============================================================
# 1. Parameter setting (Using the recent average fluctuation characteristics of SAP)
set.seed(****)
last_price <**** SAP Reference stock price (**)
m* <***** # Estimated average daily yield rate
si*** <****** # ******** Set daily volatility rate
*_days <- 30 # Trading Day
*_*** <- *****. # Simulation times
# 2. Core Monte Carlo Simulation (Path Generation))
rand_shocks ****(rnorm(*_days * n_sim, **** = **, sd = sigma), nrow = ******)
price_paths <- ****_***** * exp(apply(****-*****, 2, cumsum))
# 3. Calculate the final statistical indicators
Median_res < apply*****
Lower_5 < apply*****
```

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```
Upper_95 < apply*****
# 4. Final Output Value
Cat (***SAP's stock price forecast for the next 30 trading days***)
Cat (***)
Cat (***)
Cat (***)
Cat (***)
# 5. Drawing
Plot (1:n_days, median_res, type="*", ***=3, col="blue",
Ylim=range************
Main=*****
Xlab=*****
Lines(lower_5***)
Lines(upper_95***)
Legend("topleft" ***), lty = c (1,2,2), lwd
```

4.2. Analysis of simulation results

Table 1. Data value of price trend prediction

	Values
Last_price	215
Lower_5	num[1:30] 210 208 206 205 204 …
Median_res	num[1:30] 215 215 215 215 215 …
Mu	0,0004
n_days	30
n_sim	10000
sigma	0.015
Upper_95	num[1:30] 220 223 225 226 227 …

As indicated in Table 1, it shows that simulating 10000 times in sigma 1.5% that the daily volatility rate. This is the result that the last stock price was 215 Euro, the 30-day forecast median was 215 Euro, 5% downward limit was 164.93 Euro, which was the average price by taking 10000 simulations, and the average of 95% positive upward limit was 189.15 Euro.

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4.3. Chart analysis

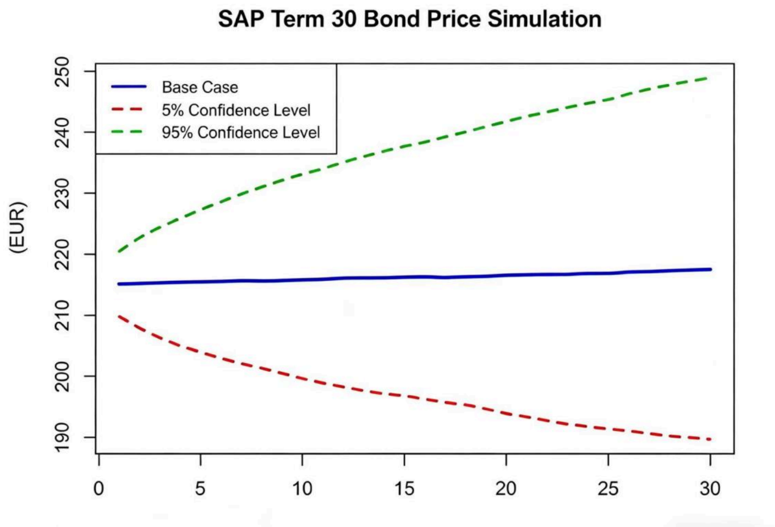

Figure 1. SAP stock price forecast - 30 trading days

Figure 1 indicates that the blue line in the median of SAP will remain stable in the future 30 trading days, approximately 215 Euro from the graph. Apart from this, the figure of 5% line represents the remarkably increasing trend from 220 Euro to 248.5 Euro, while the statistics of 95% line show the sharply downward trend between 210 Euro and 190 Euro in the future 30 trading days.

5. Conclusion

This essay discusses the Stock Investment of Risk Assessment for Listed Companies SAP Based on ARMA-GARCH model and Monte Carlo Simulation, to get the prediction of stock price trend for the listed company SAP, which can be a reference for investors. The results are as follows: a. Trend analysis: The stock price of SAP will remain stable in the future 30 trading days around 215 Euro, and the statistics of median represent an upward trend of approximately 1.06%. b. Risk level: The 5% downward risk line demonstrates the maximum potential decrease movement around 9.523%. The short-term downside risk is steerable. c.Upward potential: The 95% positive upside bound indicates the upward space is 12.955%, which shows the short-term is flexible. Apart from this, this essay has some limitations and outlook, for instance: This model applied the standard GARCH model without considering the asymmetric volatility effect, and cannot fully demonstrate the impact of negative news. And then, the ARMA model can only capture linear relationships, which can not reflect the nonlinear structural changes in stock prices. This experiment does not take into account real-world events like Black Swan Event, etc. And only utilize the data of historical price, which does not include the exogenous variables such as Macroeconomic or Microeconomic, Industry and Company Fundamentals. In the future, people can utilize some model, such as EGARCH or multi factors framework, as well as increase simulation times to further enhance the prediction accuracy.

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