GOLD PRICE PREDICTION BASED ON THE MONTE CARLO METHOD

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Abstract: Gold is a precious metal that attracts the attention of authors from various fields. Due to its wide application in various industries, it is a very important resource for the business of many companies. In this paper, the price of gold was predicted for a period of one year, based on historical data, for approximately five years. Price forecasting was performed based on the Monte Carlo method, and the simulation itself was performed in the MATLAB software. The aim of this paper is to help the management of companies for which gold is a significant resource in planning and making business and financial decisions. The result of the forecast allows the management to create different scenarios to be ready to react to almost any situation on the market, and thus to maintain the position of the company they lead.

Keywords: Monte Carlo method, Price prediction, Gold market, MATLAB.

1. INTRODUCTION

Gold is a precious metal because of its specific physical and chemical characteristics. This metal has been highly valued throughout the world for centuries. Due to its wide and specific use, it is considered a highly sought after commodity. Global demand for gold is met from two sources. The first, the dominant one, involves the mining of gold, while the second refers to the supply of gold from recycled sources to the world market. The largest producers of gold in the world are China (375t), Russia (324.7t) and Australia (313.9t) (World Gold Council, 2024). These countries produce about 1,000t of gold per year. Gold production for the period 2010-2023 is given in Figure 1 (World Gold Council, 2024).

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Figure 1. Gold production sources and average market price for period 2010-2023
(Adjusted according to World Gold Council, 2024)

Figure 1 shows that gold production for the observed period has a slight increase. Figure 1 also shows the movement of the average price of gold per unit Oz, for the observed period. As can be seen, the price fluctuates during the observed period, but since 2020 there has been an increase in the price of gold, expressed in USD per Oz unit.

Gold has a very wide range of uses. According to data available on the World website Gold Council Gold's miscellaneous uses, in jewelry, technology and by Central banks and investors, mean different sectors of the gold market rises to prominence at different times points in the global economy cycles. The use of gold in the world market for the period 2010-2023 is given in Figure 2.

Figure 2. The use of gold in the world market for the period 2010-2023
(Adjusted according to World Gold Council, 2024)

In Figure 2, it can be seen that during the observed period, the use of gold was mostly directed towards the production of jewelry. In addition, gold is used for investment, in the production of technological components, as well as in banks in the form of reserves.

Based on the above, gold is a very important resource in the business of companies around the world, which operate in the mentioned areas (Figure 2), but gold is not only used in these areas. Due to its wide application, monitoring the movement of the price of gold is extremely important, so that the management of the companies that use it can make timely and correct business decisions. The goal of this paper is to forecast future price movements based on gold prices on the stock exchange from the previous time period, based on which the management of the company can make business decisions or plan future activities. After a short introduction, the paper will present the use of the Monte Carlo methodology in stock price
forecasting, after which the methodological approach to price forecasting and initial data will be presented. Finally, the paper will present the obtained results and concluding considerations, i.e. guidelines that could be helpful to managers in business and financial planning.

2. LITERATURE REVIEW

Gold price volatilities have a significant impact on many financial activities of the world. Gold, as a very well-known precious metal, is very attractive for a lot of authors in different spheres of researching, and the gold price prediction is a subject that leads. Accurate forecasting of prices is a very challenging task due to the volatile and nonlinear nature of the financial stock markets (Jevtić et al., 2023). Researchers and academicians are still working on the best way in finance and economics to conquer this challenge (Makala & Li, 2021).

In the literature, there are authors that focus their research on the stock price prediction (Shafiee & Topal, 2010; Jevtić et al., 2023; Čečević et al., 2023). Some authors in their research provided a review of available methods for gold price prediction (Zainal & Mustafa, 2015). Some authors (Brabenec et al., 2020; Salis et al., 2019) used combination of various methods in their stock price predictions research. Sami and Junejo (2017) in their research used techniques based on the machine learning, while Manjula and Karthikeyan (2019) did a combination of machine learning and regression analysis. Some authors did the prediction using the deep learning techniques (He et al., 2019; Vidya & Hari, 2020; Dhanush et al., 2021). Some authors used ARIMA model for stock price prediction (Makala & Li, 2021; Yang, 2019; Tripathy, 2017), while the others used a combination of ARIMA model and neural networks (Adebiyi et al., 2014).

Many of them focused on the gold price predictions using one specific method. Madziwa et al. (2022) in their research did gold price prediction based on the multivariate stochastic model. Xiang et al. (2021) for the gold price prediction used Monte Carlo method. Some authors in their research, beside gold price prediction based on Monte Carlo method, analysed gold price returns (Chai et al., 2021). Many of them combined Monte Carlo method with other available methods for not only predicting gold price but the risks, too (Baur et al., 2016).

Monte Carlo method is widely used for stock price prediction in various industries and used by some groups of authors (Brodd & Djerf, 2018; Xiang et al., 2021; Jevtić et al., 2023; Čečević et al., 2023).

Based on the review of the literature, there are different groups of authors who base their research on predicting the price of gold using different methodologies or their combination. Nevertheless, the literature review indicates that price prediction can also be performed using the Monte Carlo method, which has not been widely applied to the given topic. Therefore, the contribution of this paper is that it provides a new perspective of price forecasting that can be used as a basis for making important business and financial decisions. In the following, this methodology will be explained, and the results of the conducted simulation will be presented.

3. METHODOLOGY AND DATA

The Monte Carlo method is a numerical method for solving the most complex requirements. Stanislaw Marcin Ulam, Enrico Fermi, John von Neumann, and Nicholas Metropolis are considered the first authors who gave importance to this method and its application. Ulam applied this method to games of chance. After extensive research, he managed to develop the pattern into a two-dimensional game based on very simple rules. His
work was the basis for the development of far more complex methods in engineering. The potential of this method was soon recognized by John von Neumann, who wrote a program for the first computer, ENIAC, which was used to solve the problem of neutron diffusion using the Monte Carlo method (Jevtić et al., 2013).

Hertz (1964) is one of the authors who analysed the potential of using the Monte Carlo Method (MCM) in the field of economics. Monte Carlo simulation is a method of analysis based on artificially recreating a random process (usually using a computer), running it multiple times, and directly observing the results (Barreto & Howland, 2006). Very simple as well as very complex problems can be solved by simulation. Some problems can be solved manually. However, most require the use of software, such as Excel, R Studio, MATLAB, and similar. Without these programs, solving certain problems would take a very long time (Jevtić et al., 2023).

In this paper, gold price prediction (forecasting) is done for a period of one year (the average number of trading days on the stock exchange is 252, so that value is considered representative) using the MATLAB software. Prediction is done based on the historical data for adjusted closing market prices for period of approximately 5 years (approximately 1350 working days) or more specific for period since 1st of January 2019 to 30th of April 2024. Data are downloaded from Yahoo finance (2024) that provide stock price information. For Gold, data are redistributed from the stock market COMEX LME. Prediction is set for 1,000 outcomes.

To use the Monte Carlo method for the price prediction, the historical data have to be stochastic. Thus, the first step in the simulation is to determine the type of data that is included. Figure 3 presents the historical data for the observed period.

![Figure 3. Gold prices for period 1st of January 2019 to 30th of April 2024 in USD per Oz (Adjusted according to Yahoo finance, 2024)](image)

Figure 3 represents that the gold’s price movement for the analysed period has a stochastic character, as there can’t be described function that explains this change. Therefore, this data is suitable for running the Monte Carlo price prediction. For the analysed period, some statistical data is presented in Table 1.
Based on the data shown in Table 1 it can be observed that for the observed period price has significant changes as the minimum price was 1,269.3 USD/Oz, while the maximum was 2,398.4 USD/Oz, and the average price for the analysed period is 1,765.8 USD/Oz.

Based on the corresponding code written for usage in software MATLAB, the normalized daily increase in the price is first computed, as well as the mean value and standard deviation for these data. Since this method of prediction is based on probability, the next step is the generation of random numbers. To generate random numbers, a function that recognizes the normal distribution of the numbers is used. Those random numbers represent simulated price increases for the future period based on which the price forecast for the future period is made (Jevtić et al., 2023).

4. RESULTS AND DISCUSSION

Price forecasting in this paper is done using the code for MATLAB. Prediction is based on the historical prices (adjusted closing prices) for the period from 1st of January 2019 to 30th of April 2024. Prediction is done for one year in future which is approximately 252 working days. The case of wanted scenarios is set to 1,000. The results of price prediction for the observed period is presented in Figure 4.

![Figure 4. Gold price prediction results for predicted period of 252 days and 1,000 outcomes](image)

On the Figure 4 the x-axis presents the number of days for which price is predicted, and on the y-axis presents the predicted price in USD/Oz. Regarding that the historical data is already determined as stochastic and with significant volatility, the prediction results vary, too. The comparison of historical data and predicted values is an additional analysis, based on which can be noticeable the variety of different scenarios. The comparison is presented in Figure 5.
Simulation volatility for the whole period of 252 days is shown in Table 2.

<table>
<thead>
<tr>
<th>Data type for observed period</th>
<th>Maximum price</th>
<th>Minimum price</th>
<th>Average price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data value (USD/Oz)</td>
<td>4,188.2</td>
<td>1,550.0</td>
<td>2,433.6</td>
</tr>
</tbody>
</table>

Based on data presented in Table 2 it can be noticed that taking into consideration all 1,000 outcomes price can vary between 1,550.0 USD/Oz which is minimum predicted price to 4,188.2 USD/Oz which is maximum predicted price, but the most possible price will be close to 2,433.6 USD/Oz as this is the average price for the whole observed period.

Next part of the analysis is related to the distribution of simulated data. Figure 6 presents the data distribution for simulated values on 252\textsuperscript{nd} day.
Figure 6 presents the distribution of simulated prices on 252\textsuperscript{nd} day. The values on the x-axis indicate the most common values of the prices of the simulated actions in USD/Oz, whereas the y-axis reflects the number of times each price is repeated. In addition, the figure illustrates the normal distribution of the resulting data.

The additional analysis regarding simulated values on 252\textsuperscript{nd} day provide descriptive values of the results, which is presented in Table 3.

Table 3. Descriptive statistic values of price for 252\textsuperscript{nd} day of prediction

<table>
<thead>
<tr>
<th>Data type for observed period</th>
<th>Maximum price</th>
<th>Minimum price</th>
<th>Average price</th>
<th>Standard Deviation</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data value (USD/Oz)</td>
<td>4,136.7</td>
<td>1,566.5</td>
<td>2,588.3</td>
<td>398.6458</td>
<td>12.6063</td>
</tr>
</tbody>
</table>

Table 3 presents the descriptive statistic values of predicted gold’s price. In 252 working days (one year) according to prediction the price will vary between 1,566.5 USD/Oz and 4,136.7 USD/Oz. The most probably price will be close to the average which is determined at 2,588.3 USD/Oz. Standard deviation of 398.6458 USD indicate to significant volatility of the price, while standard error indicates average price deviation per scenario which is approximately 12.6 USD.

5. CONCLUSION

In this paper, the gold price prediction was done using the Monte Carlo method, based on the code prepared for MATLAB. The analysis was conducted based on the historical data downloaded from Yahoo finance (2024) for the period from 1\textsuperscript{st} of January 2019 to 30\textsuperscript{th} of April 2024. The required number of outcomes was 1,000, and the prediction period was determined to be one year (252 working days).

As the historical (input) data had a significant level of volatility, the results also indicate a significant level of volatility. By comparing input data statistics (Table 1), data simulated for the whole period (Table 2), and data simulated on the 252\textsuperscript{nd} day (Table 3) it can be concluded that the longer period of prediction is, the greater volatility can be expected.

Although forecasting can never provide the most accurate results, it is still a useful tool for company management as it provides some basic guidance on potential price movements. Based on the information about the minimum, maximum and average expected prices in the future, the management can create various business scenarios and, depending on the actual situation, react readily to whatever scenario befalls the company it manages.

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