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STOCK PRICE PREDICTION BASED ON THE MONTE CARLO METHOD

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Abstract: The automotive industry market has always been very specific. Today, this market is even more demanding, because the principle of the products offered there is changing fundamentally. The electric cars that are on the market today are still in the early stages, but they have great potential. In this paper, a prediction was made on the stock prices of Tesla, Inc., one of the pioneers in the industry of electric cars. The forecast of stock prices of this company was made for one year, i.e. for 252 trading days settled on the Monte Carlo method. MATLAB software was used for the forecast based on three years of historical data on stock prices. The results of the simulation performed show that the longer the forecast period, the greater the deviations from the historical data. From the predicted values, it can be concluded that the stock price volatility varies greatly in the case of 10,000 possible outcomes and for different prediction periods. In addition to the extreme values of the predicted stock price for the observed period, the most frequently predicted stock price value is close to the average historical price.

Keywords: Automotive industry, Stock price movement, Monte Carlo method, Price prediction, MATLAB, Tesla Inc.

1. INTRODUCTION

The high pollution and climate change affecting nature have indicated the need for a sustainable lifestyle. Since cars became one of the basic products people have used to satisfy their needs, and since they are called big polluters, they have become a threat to the world. This situation created a new market for so-called green or ecological products and the opportunity for new companies to compete. One of these is Tesla, Inc.

Tesla, Inc. was established in 2003 in California (United States). Since 2008, when the biggest shareholder, Elon Musk, became the company's CEO, Tesla started to grow rapidly and became the world's most recognizable electric vehicle producer. Today, it is an American multinational automotive and clean energy company headquartered in Austin, Texas, the most recognizable products are electric vehicles, batteries, and solar systems (Tesla, nd).

In 2021, the global fleet of Tesla vehicles, energy storage, and solar panels enabled its customers to avoid emitting 8.4 million metric tons of CO2e (Tesla, 2021, p.3). The same year, Tesla, Inc. produced 25.39 TWh on its solar systems. The production output for 2022 was

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1,369,611 electric vehicles. Some business results of this company for 2022 are presented in Table 1.

Table 1. Tesla, Inc. business results for 2022 (Yahoo Finance, 2023)

Business Results	Revenues	Operating Income	Net Income	Total Assets	Total Stakeholders' Equity
Value (USD thousands)	81,462,000	13,832,000	12,583,000	82,338,000	44,704,000

Tesla, Inc. shares are listed on the stock exchange and traded daily on the stock exchange Nasdaq. The average trading volume is estimated at 166,487,579 shares. According to Yahoo Finance (2023) the major holders (51% of equity) are floats held by institutions, while 44.86% are shares held by institutions.

Based on the trading data that Yahoo Finance provides, potential investors can get some additional information about the target company. The recommendation trend is one of these data. This indicator is based on shareholders' attitudes and experience related to investment in this company. According to this indicator, Tesla's shares are evaluated at a value of 2.4 (Figure 1) which is described as the owner's attitude that rather buy additional shares of this company than keep the same quantity or even sell them.

Figure 1. Recommendation rating for Tesla, Inc. stock possession (Yahoo Finance, 2023)

The shares of this company have been traded on the stock exchange for years, and they are still tradable. According to historical data, the demand for Tesla shares has increased and so has the price. The quantity (volume) of trading is presented in Figure 2 for the period of three years (22 April 2020 – 22 April 2023, total 756 trading days at Nasdaq) that are analyzed in this paper.

Considering the great potential of this company's products, it should not be ignored that Tesla will have more and more competitors over time, especially since today almost all car manufacturers are developing their product lines for electric vehicles. Shares are important channels for raising funds for enterprises, and forecasting share prices is of great importance for equity financing, risk identification, and corporate policy formulation (Wang et al., 2022).

In this paper, a Monte Carlo simulation is used to predict the price of Tesla, Inc. shares for the future period trading year (252 working days). As it is known that when the demand for certain products (in this case shares) increases, their price also increases, the purpose of this paper is to predict the future position of this company in the market as its share price changes. The demand for shares of this company is presumed to be reflected in its share price on the stock market. That information is useful for potential investors, as well as for the company's management.

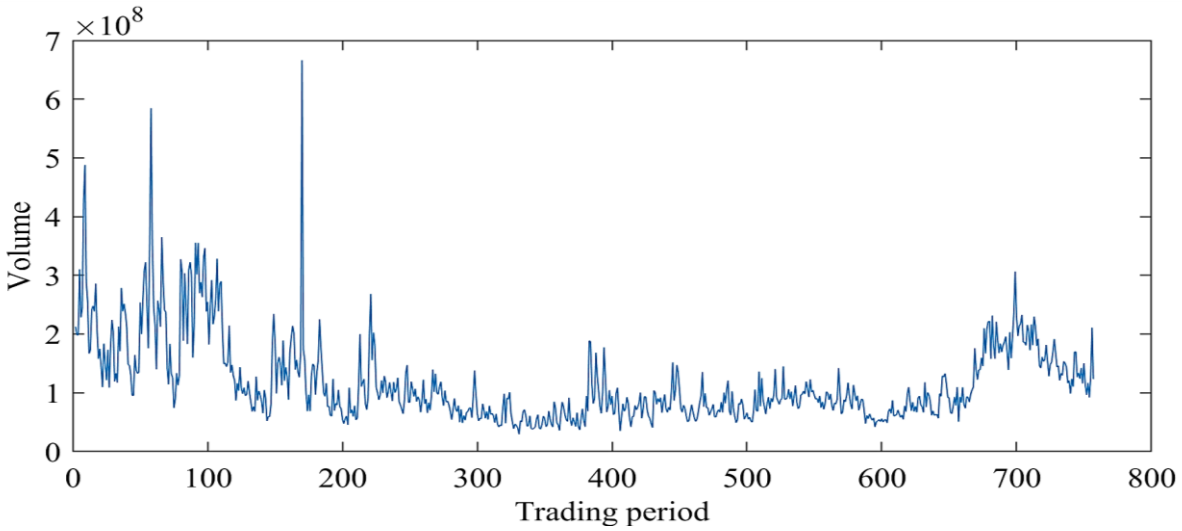

Figure 2. Tesla, Inc. trading volume at Nasdaq for period 22 April 2020 – 22 April 2023 (Adjusted to Yahoo Finance data)

Therefore, the structure of this paper is as follows. After the brief introduction and review of the literature based on the automotive industry and the use of Monte Carlo simulation for price prediction, the results of the simulation will be discussed.

2. LITERATURE REVIEW

Vehicles (cars) are regarded as the most common mode of transportation nowadays. This means that millions of people use it every day. Due to the specificities of the products themselves, the automotive industry is one of the fields most analyzed from a theoretical and practical perspective. Electric vehicles are the most attractive of them. Numerous world experts analyse these products or its producers from various points of view. Here, the focus will be only on those authors that analyse the economic and financial aspects of automotive companies that produce electric vehicles. Special attention is paid to research in the field of price movements of shares of companies on the market.

One of the most popular topics in the automotive industry is the relationship between environmental and economic issues. Many authors concentrate their research on identifying the relationship between these two mutually exclusive categories (Liu et al., 2018; Rovinaru et al., 2019; García-Machado & Martínez-Ávila, 2019; Meckling & Nahm, 2019; Gohoungodji et al., 2020; Haas, 2021; Hu et al., 2021; Szász et al., 2021; Palea & Santhià, 2022; Beier et al., 2022; Lukin et al., 2022).

There are some authors that focus on a comparative analysis of competitors in the automotive industry (Scavarda et al., 2009; Shah & Regassa, 2010; Lui et al., 2018; Gorgoni et al., 2018; Mordue & Sweeney, 2020; Lukin et al., 2022). Some of them in research focuse on trends in the automotive industry globally or in individual economies (Truett & Truett, 2007; Salihoglu & Salihoglu, 2016; Saidani et al., 2018; Masondo, 2018; Albulescu et al., 2021).

Accurate forecasting of stock prices is a very challenging task due to the volatile and non-linear nature of the financial stock markets. In recent literature, there are authors who deal with the prediction of the share price of automotive companies, using different methods or their combination (Nguyen et al., 2019; Yu & Yan, 2020; Anand, 2021; Rakhra et al., 2021). Scott (1985) for the stock price prediction in its research combined regression analysis and the Monte Carlo method. Estember and Maraña (2016) used a combination of Monte Carlo and artificial

neural networks. There are many authors that implement artificial intelligence for stock price prediction (Ray et al., 2018; Sangeetha et al., 2021; Chopra & Sharma, 2021). In their research, some authors (Vijh et al. 2020; Mokhtari et al., 2021) focused on stock price prediction using machine learning techniques.

Some authors (Fathi Vajargah & Shoghi, 2015) used the Monte Carlo method for predicting the stock market index and the value of total risk, while others used this method for stock returns prediction (Kumar & Yadav, 2021). Azis et al. (2021) used the Monte Carlo method for the prediction of the movement of the net asset value. Hersugondo et al. (2022) used the Monte Carlo method for stock price prediction and prediction of some stock indexes.

Based on the given literature review, it can be stated that there is no paper that deals with the prediction of stock prices in the automotive industry using the Monte Carlo method. In this respect, the contribution of this work resides in the different approaches and methods used. In this paper, the stock price prediction will be performed based on the Monte Carlo method using MATLAB software for Tesla, Inc. In the following, the methodology used in the research will be explained, as well as the results of the simulation.

3. DATA AND METHODOLOGY

3.1. Data

The share price prediction for Tesla was created based on historical data available on the Yahoo Finance website. Stock market data is publicly available for all companies within a single stock market. These data are displayed on a daily, monthly, or quarterly basis. As trading on the stock market is a dynamic process, stock markets provide data related to the opening and closing prices, which may be different. Also, the trading volume may differ, too. Since studies usually use the Adj. Price, i.e., the adjusted closing price, to analyse companies on the stock market (from the point of view of the share price), this study will also use this price type as the input data for the analysis.

Monte Carlo analysis focuses on the analysis of stochastic data. Thus, the first step in the simulation is to determine the type of data that is included. Here, the historical data was used for the prior three years (22 April 2020 – 22 April 2023, total 756 trading days at Nasdaq) as the automotive market is dynamic and prior changes may not be relative to the future trends.

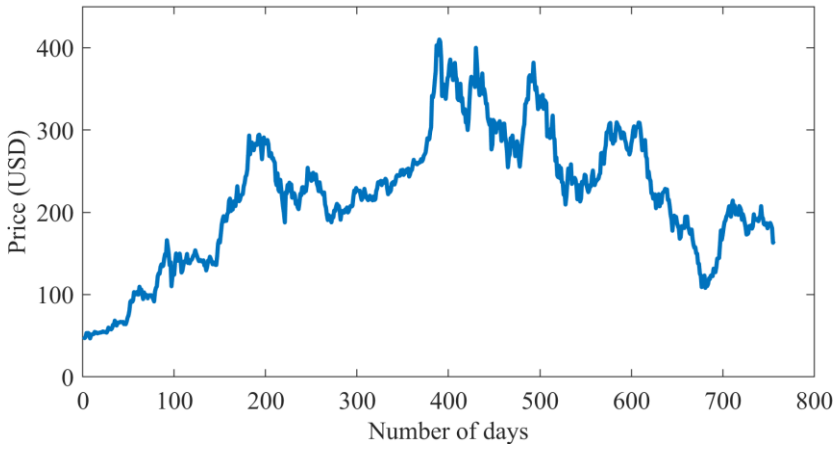

Figure 3. Tesla stock price movement for period 22 April 2020 – 22 April 2023 (Adjusted to Yahoo Finance data)

Figure 3 presents that the stock price movement for the Tesla company for the observed period has a stochastic character, as there can't be a clearly identified data trend for the observed period. Therefore, this data is suitable for running the Monte Carlo price prediction. For the observed period, some statistical data is presented in Table 2.

Table 2. Descriptive statistic values for Tesla stock prices for the observed period (Authors)

Data type for observed period	Maximum price	Minimum price	Average price	Standard deviation
Data value (USD)	409.9700	46.7547	219.8989	80.1993

Based on the data presented in Table 2 it can be noticed that for the observed period stock price had significant changes as the minimum price was 46.75 USD, while the maximum was 409.97 USD, and the average price for the observed period is approximately 220 USD.

3.2. Methodology

The Monte Carlo method is a numerical method for solving the most complex requirements. It is a statistical method that was invented in 1946 by Stanislaw Ulam while he was working on the development of nuclear weapons. As it is a secret project, it got its name from the Monte Carlo casinos where's Ulama's uncle often gambled (Crnjac-Milić & Masle, 2013), and it is believed that the casino was also the inspiration for the creation of this method. The basis of this method is the creation of randomness and the process of repetition.

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 (Metropolis, 1987).

Hertz (1964) is one of the authors who analyzed the potential of using the Monte Carlo Method (MCM) in the field of economics. He found certain peculiarities of the Monte Carlo method and gave an answer to the question of whether there is a way of risk analysis that can help managers make wise decisions, launch new products, modernize plants or avoid overloading of technical capacities. Mathematical formulas that guarantee a uniform rate of return are not enough. The author emphasizes the type of data used and the specific combination of variables, such as cash flow and return that can lead to the routine application of risk analysis in everyday business or in any decision-making process.

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.

Monte Carlo simulation i.e. stock price prediction for the future period of one year (the average number of trading days on the stock exchange is 252, so that value is considered representative) is performed using the MATLAB software. The prediction is made individually for the sequences (quarters) of the prediction period. The prediction period is divided into

quarters. Therefore, for the 10,000 outcomes the stock price prediction is done for period of 63 days, 126 days, 189 days, and 252 days respectively.

The prediction is made individually for the selected periods. Based on the corresponding code, the normalized daily increase in the share 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.

The figures are created according to simulated prices whose interpretation will be set out in this paper.

4. RESULTS AND DISCUSSION

Stock price prediction for Tesla is done based on the three-year-old historical data for the future period of one year on a quarterly basis. As approximately one trading year has 252 working days, the prediction has been done for 63 days (one quarter), 126 days (two quarters), 189 days (three quarters), and for the whole trading year (252 days). The results of stock price prediction for the observed period are presented in Figure 4.

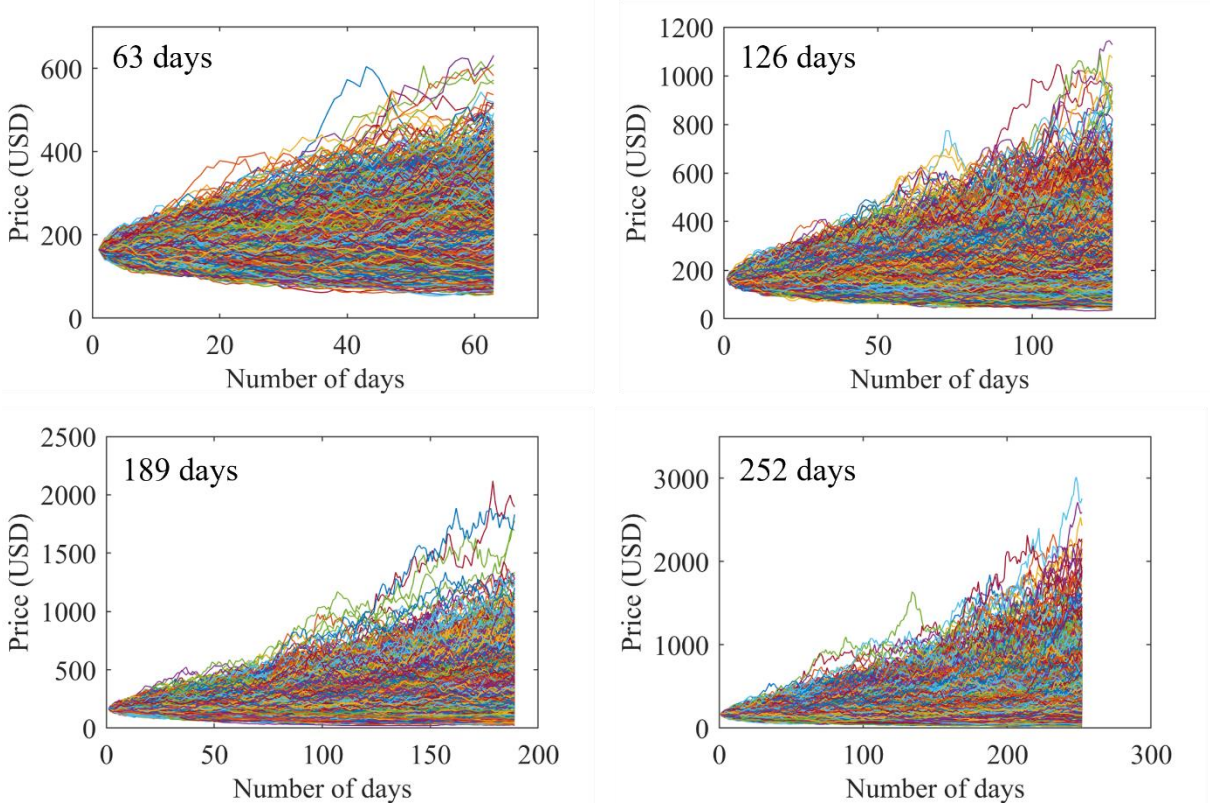

Figure 4. Stock price prediction results for predicted period of 63 days, 126 days, 189 days, and 252 days and 10,000 outcomes (Authors)

Figure 4 shows the stock price prediction results for four future quarters. The x-axis presents the number of days in the future (prediction period), and the y-axis presents simulated prices. All predictions are made based on the 10,000 cases (simulations) as the more simulations are done, the more precise the results are. Taking into consideration that the historical results

are already described as stochastic and with great price volatility, the simulation results vary, taking into consideration the prediction period. The results show that the longer the prediction period is, the greater the possibility for higher stock prices.

Figure 5 presents the distribution of simulated share prices on days 63, 126, 189, and 252. The values on the x-axis indicate the most common values of the prices of the simulated actions, 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.

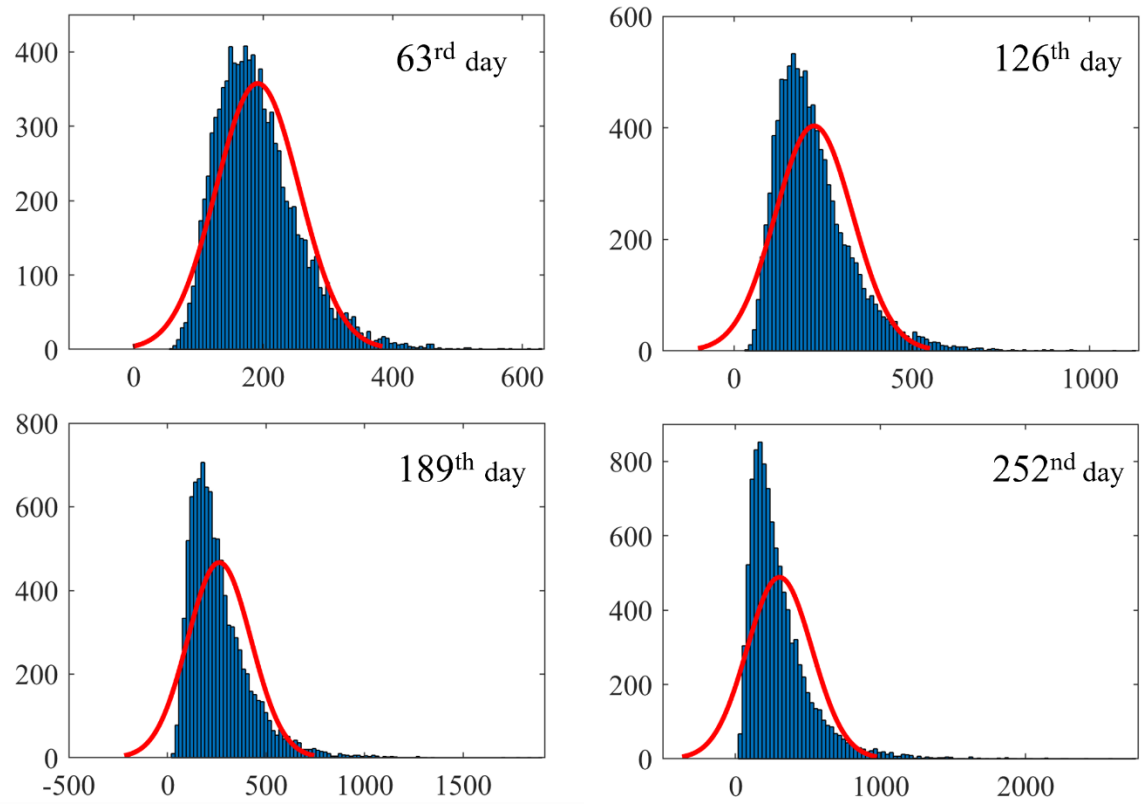

Figure 5. Distribution of simulated share prices on days 63, 126, 189, and 252 for 10,000 outcomes (Authors)

By observing the most frequently predicted prices, it is noticed that the difference in the average predicted prices exists even though the overview periods are short. Table 3 presents more detailed data on price volatility for all observed periods.

Table 3. Simulated price volatility for the observed period and 10,000 outcomes (Authors)

Price (USD)	Prediction period			
	63 days	126 days	189 days	252 days
Minimum	53.7133	32.4338	19.9660	20.4021
Average	177.7958	193.9756	210.9434	227.9592
Maximum	630.8688	1,144.3000	2,119.8000	3,013.4000

Based on the values shown in Table 3 it can be noticed that the longer the period of prediction is, the wider the range in price will be. Based on the historical values, if the prediction is for one quarter (63 working days) the price will vary between approximately 53 USD and 630 USD, while the average price would be approximately 178 USD. In the prediction period is two quarters (126 days), the price will vary in the range of 32 USD minimum, and 1,144

USD maximum. In this case, the most probable average price will be approximately 193 USD. For the prediction period of 189 days or three quarters, the price varies more. The price range that is determined is between approx. 20 USD (minimum) and approx. 2,120 USD (maximum). In this scenario, the average price, and at the same time the most expected, is about $211. For the longest forecast period, the price fluctuates the most. The price range is between about 20 USD and 3,013 USD. However, the average price for this period is about 228 USD. Compared to the historical data, for which an average price of about 220 USD was calculated, the average price for the longest forecast period comes closest to this value.

Additional analysis related to this simulation can be done by comparing the historical (input) data with the obtained results. Comparing them, it would be noticeable the variety of different scenarios. Figure 6 presents the overall view of historical and obtained data for the period of the whole year.

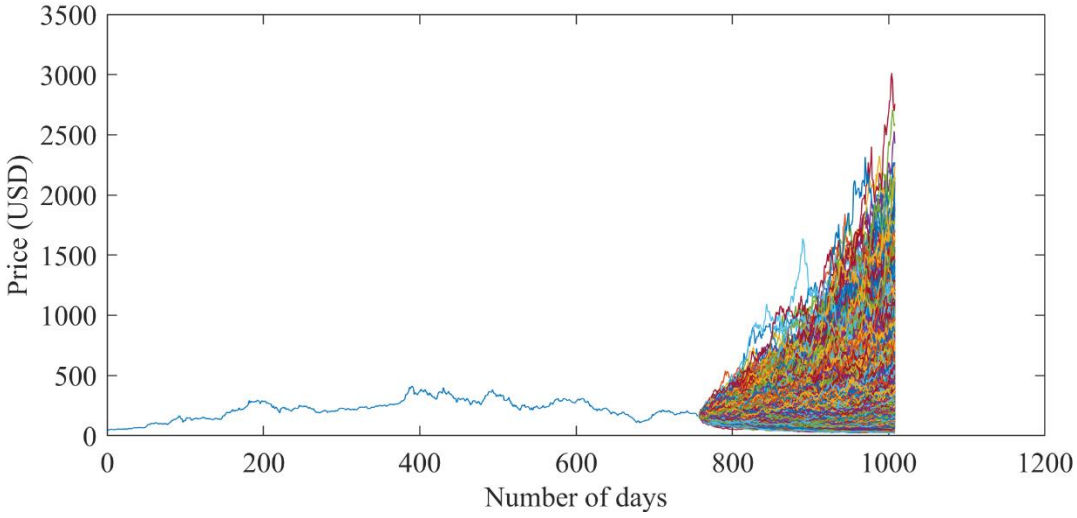

Figure 6. Summarized historical data and predicted prices for the observed period of 252 days and 10,000 outcomes (Authors)

5. CONCLUSION

The automotive industry market has always been very specific. Strong competition between manufacturers who offer different products to their customers has characterized it. Today, this market is even more demanding, as the principle of the products offered on it is fundamentally changing. The electric cars that are on the market today are far from the classic cars in terms of their characteristics, but the number of models and manufacturers of these innovative cars is increasing with time. In other words, this market is still in its early stage.

In this article, a forecast of the stock prices of a company whose primary products are electric cars was made. The Tesla company is one of the pioneers in the production of electric cars. Historically, this company has been in business for about as long as electric car production has been in development. In such a short period, this company attracts a lot of attention from stakeholders. For this reason, it was selected for analysis. The forecast of this company's stock prices was made for one year, i.e. for 252 trading days, based on three years of historical data on the development of stock prices. MATLAB software was used for the forecast, in which a simulation based on the Monte Carlo method was performed.

To see how the length of the forecast period affects the future, the simulation was performed for four different periods (63 days, 126 days, 189 days, and 252 days), and for each one 10,000 cases (possible outcomes) were run. The results of the simulation performed showed

that the longer the forecast period, the greater the deviations from the historical data. In other words, a longer forecast period will result in a wider range of possible price movements in the future, as you can see in Table 3. Table 3 also shows that the average price also depends on the length of the forecast period. There is a direct correlation between the length of the forecast period and the level of the average price. It is also interesting to note that the average price for the forecast periods of 189 and 252 days is close to the average price calculated based on historical data (see Table 2).

Considering that this method is based on probabilities, it is ungrateful to expect that its application will lead to accurate predictions. Moreover, the forecast is based on historical data, so it reflected any sudden price change in the past as a possible jump or fall in the future. On the other hand, the uncertainty of future events cannot be taken into account when using this method.

The final conclusion that can be drawn based on the analysis performed is that, for the forecast period of one year, this method provides values that do not differ significantly from historical values and reflect the direction of price movements in the future. When uncertainty in the future is excluded, this method can provide investors with satisfactory guidance on whether to invest in a company. The results of this analysis show that the price of Tesla stock will continue to rise in the future, so it is worth investing in it. It is recommended to make the final investment decision based on several analyses to compensate for the shortcomings of each forecasting method.

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