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Monte Carlo Simulation Prediction of Stock Prices

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***Abstract*— Stock market provides limitless opportunities for average income earners to grow their wealth. Nevertheless, it is well-known that most people lose their cash by investing in it. This study investigates the statistics of market volatility by obtaining and analysing data sources from financial websites using Python programming language. The implemented method uses a mathematical model called Geometric Brownian Motion (GBM) in order to simulate stock prices in the United States and Malaysia The stocks were used as a data set for the simulations, which in turn were conducted in time periods 1000 cycle .The two main parameters which determine the outcome of the simulations are the mean return of a stock and the standard deviation of historical returns.This study provides useful insights for retail traders through the Monte Carlo Analysis in finance.**

Keywords— Stock Market, Monte Carlo Analysis, Geometric Brownian Motion Model, Market volatility

I. INTRODUCTION

The financial market is a prime example of a complex stochastic system. Monte Carlo Simulations are an incredibly powerful tool in numerous contexts, including operations research, game theory, physics, business and finance, among others. It is a technique used to understand the impact of risk and uncertainty when making a decision The high level of uncertainty and randomness of the market is due to the daily changes in the supply and demand of stock prices influenced by the fear and greed of investors and traders from across the globe. According to the efficient market hypothesis (EMH), the market discounts all known information where the share prices reflect a fair value [1]. Hence, it is impossible to beat the market in the long run. However, hedge funds can consistently beat the market, for instance, the holding company of Berkshire Hathaway managed by the Sage of Omaha Warren Buffett returned 20.5% annually on average, compared to the S&P500 index which returns only 8% annually on average.

Some traders make consistent profits from the market on a year-by-year basis. Hence, various scientific models were developed by mathematicians in an attempt to forecast future stock prices. The models include neural networks, fuzzy inference systems and machine learning techniques, various ARIMA models, Monte Carlo simulation, and GARCH model [2], [3]. One such model is the Geometric Brownian Motion (GBM) model, which was discovered by Robert Brown in 1827. This study uses the GBM to study and analyze the data from the past 10 years of historical closing prices of the Kuala Lumpur Composite Index (KLCI) and S&P500 (SPX) to determine the expected return and volatility[4] . This study mainly focused on companies listed on the United States (US) and Malaysia stock markets. GBM was chosen for this study as it uses the Monte Carlo Simulation to predict the movement of future stock prices based on the past performance of the indices.

Studying the prices of the stock market is important because the power of compounding allows small sums to snowball into huge amounts, which is quoted as the eighth wonder of the world by Albert Einstein. This article is organized in the following manner: abstract, introduction, literature review, problem statement, aims and objectives, research questions, significance of the research, research methodology, overview of the system, and conclusion.

II. PROBLEM STATEMENT

Models used to predict and forecast the future movement of stock prices are also constructed by hedge funds that receive clients' money. Since research on scientific models resulted in consistent returns for the funds, there is a need for the study in this field. Particularly, the probability modelling method that employs the mathematical approach known as Monte Carlo Simulation is suitable for this reason. Andrea and Juan,2019 used the Simulating Profit Loss in Behavioral Newsvendor Problems model to predict the probability of different outcomes using a set of parameters and random variables[5]. The function allows the simulator to make better-informed decisions by analyzing the results produced by the model.

There is a large scope for Monte Carlo applications in the area of computational biology and physical sciences. Zawin, Siti and Mohd,2020 used the Monte Carlo Simulation to model the Malaysian gold prices recently[6]. Although it is not accepted worldwide in finance and business, Monte Carlo Simulation can be applied to analyze data of the stock market, which in turn can be utilized to analyze business risks and generate potential returns. The stock market is considered risky by the general public due to the uncertainty involved and the possible risk of losing huge sums of money. According to the client data provided by a famous stockbroker Etoro, 67% of retail traders lose money[7] .This study aims to transform the results of retail traders by building upon the knowledge of Monte Carlo Analysis from researchers of other fields and applying it to the world of finance to generate alpha. The problem statement of this study is to incorporate the GBM model and data analysis into Monte Carlo Simulation, to forecast future stock prices in the stock market.

III. RESEARCH AIMS, OBJECTIVE & RESEACH QUESTIONS

This study aims to forecast future trends of the broad stock market in Malaysia and the US (KLCI and SPX), by analyzing the

historical price patterns using the Monte Carlo Simulation and GBM model to extrapolate future prices.

The four objectives set to answer the research questions include:

•To analyze historical performances of stock market indices using data analysis.

•To develop an approach based on the GBM model and Monte Carlo Simulation to extrapolate future stock prices.

•To compare and contrast the returns and drawdowns between KLCI and SPX for a better investment decision.

•To evaluate market returns in a quantitative approach and remove subjectivity by using financial metrics such as standard deviation.

The research questions are based on the four objectives to which answering the problem statement.

The sub problems to the first objective are to determine the returns of the stock market in Malaysia and the US apart from determining the relative drawdown of major market indices. The historical statistics such as the average true range and standard deviation of the KLCI and SPX indices are analyzed to determine the volatility of the stock market.

As for the second objective, determining the concepts and derivatives of the GBM model and Monte Carlo Simulation, and how can they be used to simulate future stock prices using calculus and programming were the sub problems.

To answer the third objective, the characteristics of KLCI and SPX need to be analyzed using different metrics to determine a better investment decision. The problem aims to compare both markets using appropriate and scientific metrics such as market cycles, worldwide news events, and the duration of bull and bear markets.

Finally, the research question for the fourth objective is to utilize the information of Monte Carlo Simulation from the second objective to determine the market returns of different investment styles such as dollar-cost averaging or buy and hold approach. Different evaluation methods such as technical analysis and quantitative analysis could lead to different results where this research question aims to evaluate and compare results of various financial metrics.

IV. SIGNIFICANCE OF THE RESEARCH

Based on JP Morgan's survey, 53% of the traders perceive that the predicted and real-time market conditions are the most useful data tool [8]. In other words, more than half of the traders in that survey agreed that analysis of accurate prediction trends of the market is very important. Most retail traders lose money in the stock market due to the lack of quality research, because retail traders usually do not have the access to advanced tools like institutional hedge funds.

Therefore, this study contributes by providing accurate information on the Malaysian and the US stock markets using a scientific and quantitative approach. Monte Carlo Simulation was employed in this study to provide insights to retail traders and help them make better-informed decisions based on more accurate predictions of the future overall market trend.

V. LITERATURE REVIEW

The Monte Carlo method is also used for pricing options, a financial instrument with multiple sources of uncertainty[9]. The method does not seem to be used to any larger extent for modelling the probability of stock returns. There exists some more informal work on the topic e.g. hobbyist investors but not many published scientific papers. Therefore, the research in this report will build upon the knowledge obtained from other fields than stock market modelling and apply this knowledge to a relatively unexplored research field.

a. Current Market Condition

The US stock market just recovered from the stock market crash in the year 2020 and is now breaking new highs. According to Goldman Sachs, the average return of the US stock market for the past 140 years was 9.2%[10] . Based on the figure 1 below, despite the crash due to the pandemic, the market yielded a return of 18.40% in the year 2020 surpassing its average return.

Fig 1: Performance of the SPX in the Year 2020

In the history of the stock market, the 2020 Covid crash was the fastest and steepest crash. According to the chart by LPL Research, the stock market suffered from 11 bear markets since 1956, such as the infamous Dot Com Crash and Subprime Mortgage Crisis, yet still recovering from it eventually [11].

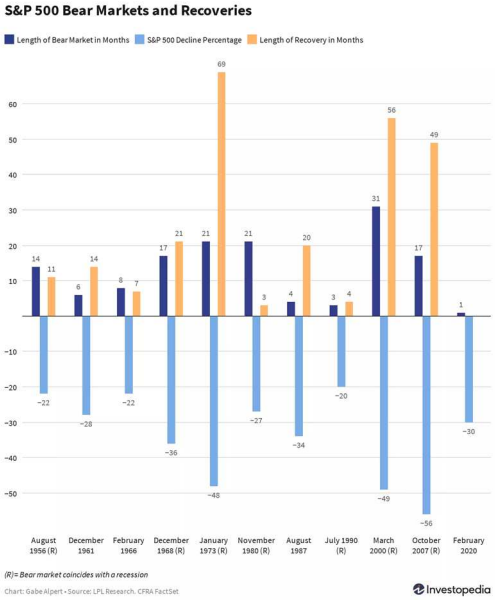

Fig 2: SPX Bear Market and Recoveries

According to the Reuters chart (Figure 2), the SPX dividend yield was still above the 10-year long term treasury bond yield of the US, which indicated that the market risk premium remained positive [12].

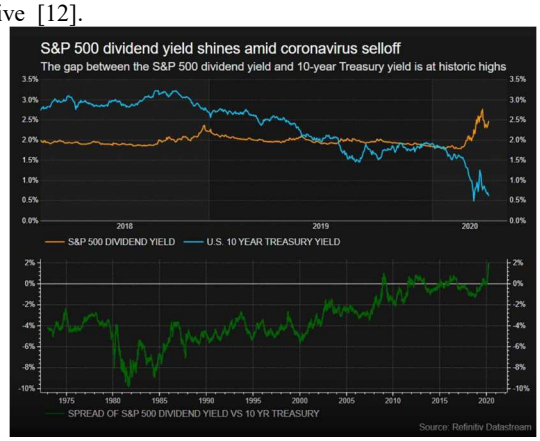

Fig 3: SPX Dividend Yield versus US 10 Year Treasury Yield

Figure 3 above shows the fundamental point of view, the stock market remains relatively cheap compared to the bond market, since the treasury bonds yield lower than the overall stock market index. As long as the market risk premium stays positive, the stock market will remain attractive relative to bonds, attracting cash flow leading to a rise in future stock prices.

b. *Geometric Brownian Motion(GBM)*

The GBM model for predicting market prices developed by Johannes Voit in 2005 is a continuous-time stochastic process, in which the logarithm of the randomly varying quantity follows a Brownian motion with drift [13].GBM is a continuous-time stochastic process that satisfies the Stochastic Differential Equation (SDE):

$$dSt = \mu Stdt + \mu StdBt \quad (1)$$

where St is a stochastic process and Bt is a Brownian motion (a Wiener
process) characterized by the following properties:

- B0 = 0
- B has both stationary and independent increments
- B has Gaussian increments

SDE in this study is that each increment in time results in the price of the stock moving with a drift (μStdt) and a shock (μStdBt). The drift can be seen as the general direction of the stock's price whereas the shock is a random amount of volatility that acts on the stock's price. The shock is what will create the curve's noise.

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process) characterized by the following properties:

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c. *Drift*

Drift which is also known as the expected daily return of the stock is derived by calculating the mean, standard deviation, and variance according to a specific period of the historical performance of the stock [14]. According to a report of Stock Price Predictions using GBM by Joel Liden, the formula of *drift* is:

$$\textbf{Drift} = \mu - \tfrac{1}{2} * \sigma^2 \quad (2)$$

Where **μ** is the mean of logarithmic returns of the stock and **σ²** is the variance. Since *Drift* provides insights on the general direction of the stock (assuming it follows a normal distribution), the past expected return of the stock is extrapolated into the future to forecast prices.

d. *Shock*

According to a recent study, Malaysian gold prices were modelled using the GBM model [6]. The study stated that the definition of *Shock* is the volatility of the asset price, which can be measured by calculating the standard deviation of the historical returns, given by the formula:

$$\textbf{Shock} = \sigma * Z\,(\text{Rand}(0; 1)) \quad (3)$$

Where **σ** is the standard deviation of the price and **Z** is a random number simulated following a normal distribution. Therefore, the future volatility of a stock using the GBM model is determined through the standard deviation of the stock and a parameter of a random weight.

e. *Monte Carlo Simulations*

Monte Carlo Simulation can be made use for predicting share price movements, when the past share prices exhibit random behaviour, without exhibiting high fluctuations [15]. Monte Carlo Simulation in the study referred to the wide range of computational algorithms which utilised randomness in some way to obtain a good approximation for probable outcomes. Once the variables of the GBM model are determined, Monte Carlo Simulations will be performed according to the formula:

$$\textbf{Price}_i = \textbf{Price}_{i-1} * e^{(\mu - \frac{1}{2}*\sigma^2) + \sigma*Z\,(\text{Rand}(0; 1))} \quad (4)$$

A certain timeframe of the stock is determined to calculate the values of *Drift* and *Shock*, followed by a Monte Carlo Simulation by applying the aforementioned formula, which can then be plotted on a graph for more data analysis. The likelihood of stock price following a given simulation is close to zero, therefore, Monte Carlo Simulations need to be repeated many times to determine the best fit line among all the simulations. The best fit line can be distinguished using mathematical models such as the Linear Regression, which calculates the most probable outcome of future stock price based on a large sample of Monte Carlo Simulations. Thus, linear regression is more reliable.

VI. RESEARCH METHODOLOGY

To analyze the performance of the US and Malaysian stock markets, data such as Open, High, Low, and Close of daily stock prices were retrieved. There are several online sources to obtain the information above. The selected platforms for this study were TradingView and Yahoo Finance, as both the platforms allow Application Programming Interface (API) to access their websites. Hence, Monte Carlo Simulation was performed to generate a future forecast of the market based on the stock prices. As such, the basic information of market prices was downloaded from the website, then exported into an Excel file for data manipulation.

Data cleaning was performed to the Excel file to remove erroneous data such as missing prices or misreported prices to assure the accurateness of the data. Next, Python programming language containing many useful built-in libraries such as NumPy and Pandas for data analysis of the stock market was used to achieve the objectives of this report. Finally, the Jupyter integrated development environment was utilized to visualize the forecasting of future stock prices through a significant number of Monte Carlo Simulations. Figure 4 shows the flowchart of research methodology.

Fig 4: Flowchart of Research Methodology

VII. RESULTS AND DISCUSSION

The Monte Carlo Analysis was performed using Python and a significant number of simulations to prevent skewed results. Parameters of the GBM model such as *Drift* and *Shock* values were based on the characteristics of market data for the past 5 years obtained from Yahoo Finance. Monte Carlo Analysis was then incorporated with the data outputs from the GBM model to simulate the future movement of market indices according to the historical volatilities.

Based on the probability theory , the monte carlo technique is widely used and recommended for including uncertainties and typically 1000 or 10000 runs are done [16]. In our study the Monte Carlo Simulation is performed on the KLCI for a sample size. The real insight in the stock and the possible outcomes of the future is gained when running thousands of simulations, by creating thousands of random price curves, which all are different, but at the same time share some of the key characteristics of the historical price data. Excessively high number of runs may be time consuming therefore in this research, 1000 runs of cycles is performed since 16/12/2020. Based on Figure 5, it can be concluded that the performance of the Malaysian stock market remained sideways or downtrend, as most of the simulations in the sample size end up closing lower than the opening price of 16/12/2020, while only a few of the simulations broke new highs. This seems to indicate that it is possible to model a stock's price using Monte Carlo simulations based on the GBM model. Most of the correctly predicted stocks increased in price for all time periods and were correctly predicted that way too. It is also noted that there were substantially more true positives than true negatives.

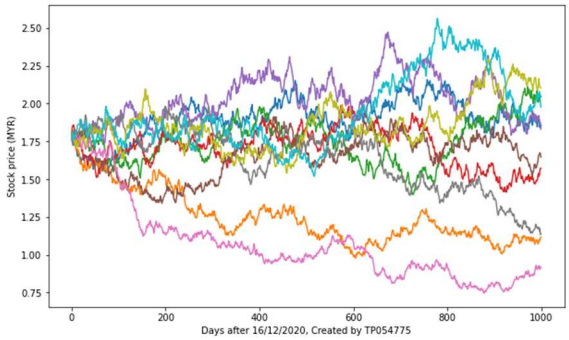

Fig 5: Monte Carlo Simulation of KLCI

Meanwhile, the simulation performed for the US stock market since 16/12/2020 indicated an upward trend (Figure 6). In short, the US stock market outperformed the Malaysian stock market based on the GBM model and would more likely break new highs in the future. Hence, the US stock market is a better investment for retail traders compared to Malaysian KLCI.

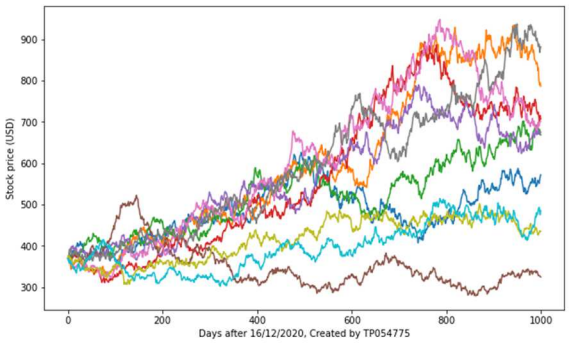

Fig 6: Monte Carlo Simulation of SPX

VIII. CONCLUSION

This study shows that it is possible to fill in the gap in the finance sector, particularly the stock market using the Monte Carlo Simulation Geometric Brownian Motion as underlying stock price model. Whereby, the parameters of the GBM model were determined based on the market characteristics of the past 5 years to perform the Monte Carlo Simulation. The accuracy of such approach turned out to be significant using our approach. Since all the objectives are achieved through the proposed system, the results can be used to assist traders to make a better-informed decision based on the past and future trends of the stock market. More research should be conducted to conclude whether the Monte Carlo method can be used for business purposes.

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