World Crises Impact on US Stocks and Future Predictions

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Abstract

This project aims to explore how major world events — Asian Financial Crisis, World Financial Crisis and Covid-19 — affected the US stock market in various aspects, including specific stocks and corresponding stock sectors. With historical data and the geometric Brownian motion model, a simulation is conducted to reveal the predicted average future return and volatility. The simulation result is then used to generate a portfolio of weighting of the stocks based on preferred risk-aversion level of the investor and the normal or crisis state of the world.

Introduction

In the complex world of finance, external shocks, such as global economic crises, can have profound implications on the performance of stock markets. The United States stock market, being the largest globally, is particularly susceptible to these influences. Over the years, events like the Asian Financial Crisis, World Financial Crisis, and more recently, the Covid-19 pandemic, have demonstrated how sudden disruptions can alter the dynamics of the market, affecting individual stocks and entire sectors.

Understanding the repercussions of such crises on the US stock market is not only intriguing from an academic perspective but also crucial for investors seeking to navigate turbulent economic times. This project aims to shed light on the interplay between global crises and stock market performance. By analyzing how these past crises have impacted the US stock market, we aim to equip investors with knowledge and tools that can help them mitigate risks and possibly even find opportunities in such adverse scenarios.

To achieve this, we delve into the historical data of six carefully selected stocks across different sectors, along with the S&P 500 index as a representative of the broader market. Our analyses will illustrate how these stocks and the overall market behaved in 'normal' circumstances and how they were affected during the times of crisis. More than just presenting the past and present, we aim to provide insights into the future. Through the use of the geometric Brownian motion model, we simulate average future returns and the corresponding volatility, providing investors with a probabilistic outlook on stock market performance. One of the key features of this study is the generation of an optimized portfolio. Using the results from our simulations, we construct a portfolio that weighs the selected stocks based on the preferred level of risk-aversion of the investor, taking into account the normal or crisis state of the market. This model portfolio is designed to serve as a guide for investors, allowing them to make informed decisions on their investments based on their individual risk appetite and the market's prevailing conditions.

Our research revolves around answering crucial questions like - How significantly do major world events affect the returns of selected US stocks and sectors? How does the volatility of these returns change during crisis periods compared to normal times? Can we predict future return trends and volatility based on past data and, if so, how accurately? Lastly, how can we optimize a portfolio of selected stocks based on the simulated future predictions and the risk appetite of investors? With this project, we endeavor to blend the fields of historical analysis, financial mathematics, and practical investing, creating a holistic view of the US stock market's performance during crises and its implications for future investment strategies. The ultimate goal is to empower investors with data-driven insights that can guide their decision-making process, making them better prepared for any economic headwinds that might come their way.

Data Sources & Methods

Our primary data source for the selected stock prices is Yahoo Finance, accessed using the open-source yfinance library in Python[1]. This library is an open-source tool that uses Yahoo's publicly available APIs, and is instrumental in obtaining accurate and timely financial data. Firstly, we install the yfinance library by using the command **pip install yfinance** in the Python environment we are working in. After installation, we import the library into our Python script using **import yfinance as yf**. For each of the selected stocks and the S&P 500 Index, we use the **yf.download** function to retrieve historical stock data. The arguments for this function are the stock's ticker symbol, the start and end date for the data retrieval period. The **['Adj Close']** operation was included to retrieve only the adjusted close price of the stocks. We also included the **.resample('M')** operation to change the frequency of the data. The 'M' argument specifies that the data should be resampled to a monthly frequency. In other words, it converts daily data into monthly data. The **.last()** operation is applied to the resampled data and selects the last observation of each period. In this context, it returns the adjusted close price on the last trading day of each month. The result is a DataFrame containing the adjusted closing price of each specified stock at the end of each month in the specified date range. This condensed monthly data can be beneficial for long-term analysis, reducing the noise inherent in daily price fluctuations.

Using the raw data obtained, we process it by applying the **.pct_change()** operation that calculates the percentage change between the current and previous adjusted closing price for all rows in the original DataFrame. This gives us the returns for each month in our time frame, which is used to calculate Cumulative Returns and simulate the Average Future Returns and Volatilities. Cumulative returns provide insight into the total return of a stock over a specified time period, and is calculated using the **.cumprod()** operation on the returns DataFrame. This was all achieved in the StockData class, which served as the foundation for data acquisition in our project. Leveraging an instance of the StockData class, this class accurately calculates and stores cumulative returns for each stock.

For visualizing the cumulative returns, the CrisisDataPlotter class plays a crucial role. This class efficiently handles the presentation of cumulative returns during crisis periods. By utilizing a dictionary of crisis periods and an instance of the SectorData class, the cumulative returns data is restructured into a suitable format for plotting. The SectorData class offers a plot_data method, utilizing the versatile Seaborn library. It generates a line plot using sns.lineplot, representing cumulative returns over time. Each sector is distinguished by a distinct line color, enabling clear differentiation and effective comparison. To delve deeper into crisis periods, the CrisisDataPlotter class provides the plot_crisis_data method. This method generates a series of subplots, each dedicated to a specific crisis period. Within each subplot, the corresponding cumulative returns data is retrieved and plotted using Seaborn. The resulting subplots are neatly organized into a 1x3 grid, providing a comprehensive view of the cumulative returns for different sectors during each crisis period.

This Python script initializes a StockAnalysis class with a list of stocks, utilizes Yahoo Finance to download their data, and subsequently analyzes their performance relative to the S&P 500 index. The script utilizes monthly adjusted close prices of stocks and the 'SPY' index. A method, plot_regression, is then employed to generate polynomial regression plots for each stock versus the S&P 500 index. This method cycles through each stock, computes quadratic polynomial fit coefficients between the stock price and the index, and plots the derived polynomial function along with the original stock prices. Additionally, it calculates the r-squared value, which measures the proportion of the variance in the dependent variable explained by independent variables, to determine the predictive power of the regression. This script essentially visualizes how closely each listed stock has mirrored the S&P 500's performance over a designated period.

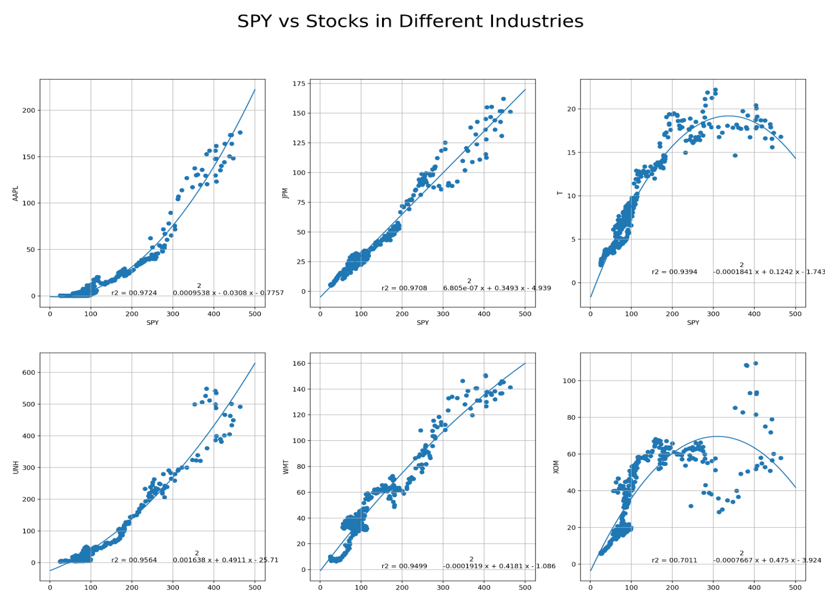
This code contains multiple classes that model stock data, calculate risks and returns, and visualize financial crises, ultimately guiding portfolio optimization. The StockData class downloads historical stock data and calculates cumulative returns. The RiskModel class uses the stock data to compute several financial risk metrics, such as mean, variance, drift, standard deviation, and simulate future returns based on a stochastic process. The CrisisVisualizer class then uses these risk models to generate future returns and volatility for normal and crisis periods, and creates bar charts to compare these returns and volatilities, based on a geometric Brownian model.

Lastly, the PortfolioOptimization class uses the calculated returns and volatilities to optimize a stock portfolio based on an investor's risk tolerance, maximizing their expected utility. The main function ties all these classes together: it first simulates average future returns and volatilities for both normal and crisis periods, displays them in a bar chart, and then uses the portfolio optimization method to provide the investor with an optimal distribution of stocks in their portfolio, depending on their risk tolerance and whether it's a normal or crisis period.

Detailed Analysis

Firstly, a regression analysis is conducted to examine the relationship between the adjusted close prices of six prominent stocks, namely Apple, JPMorgan, AT&T, United Healthcare, Walmart, and ExxonMobil, and the closing price of the SPDR S&P 500 ETF Trust (SPY). These stocks represent different sectors, while SPY serves as a reliable benchmark for assessing the overall state of the stock market. The resulting regression lines are graphically presented, along with their corresponding R-squared values and polynomial equations, to illustrate the overall trend and the reliability of the regression lines as indicators.

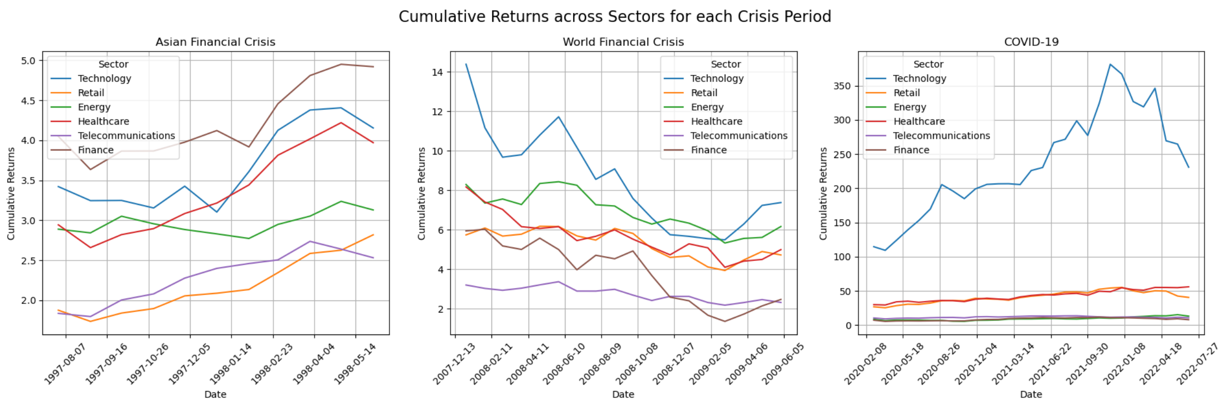
Polynomial Regression



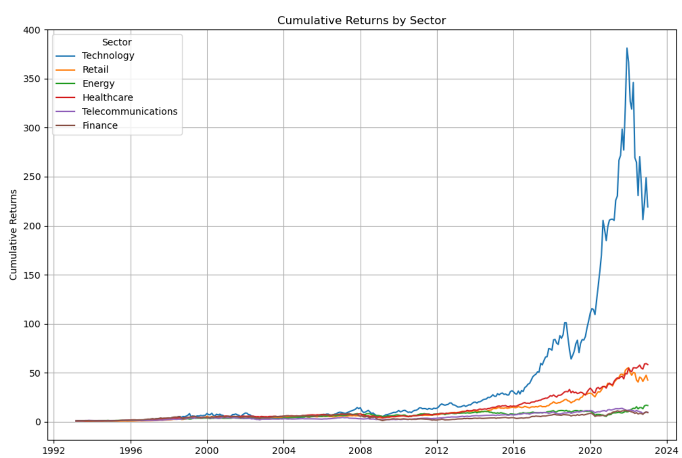
Notably, all the stocks exhibit a remarkably high R-squared value, indicating a strong level of goodness of fit for the regression equations, with ExxonMobil (XOM) demonstrating the weakest fit to the quadratic regression. While a cubic regression model could potentially be employed for XOM, the practicality of justifying a dip in the mid-price range within the context of stock prices raises some concerns. Among the analyzed stocks, JPMorgan (JPM) displays the strongest linear correlation with SPY. The coefficient of the second degree in the equation is 6.805e-07, which is extremely small and thus negligible. This finding suggests that JPMorgan's price changes at a relatively constant rate in relation to the S&P 500 index, indicating a close correlation even during periods of financial crises. Such alignment is understandable given JPMorgan's position in the financial sector, where performance is intricately linked to the overall financial market. Furthermore, Apple (AAPL) emerges as the stock least affected by market crises. When considering the number of shares outstanding, Apple exhibits the highest exponential rate of price increase compared to the index. This phenomenon can be attributed to the company's robust fundamentals and the rapid growth of technology stocks in the 21st century. Having examined the stock market trends in relation to overall market performance, our analysis now shifts focus to the returns of the sectors encompassing these aforementioned stocks.

Cumulative Returns

During the Asian financial crisis from August 1997 to May 1998, a comprehensive analysis of cumulative returns reveals that the finance sector displayed the highest returns among various sectors, with the technology, healthcare, telecommunications, and retail sectors closely trailing behind. This phenomenon can be attributed to a range of factors, including government interventions, monetary policy measures, and efforts to restructure financial institutions aimed at stabilizing the economy during the crisis.



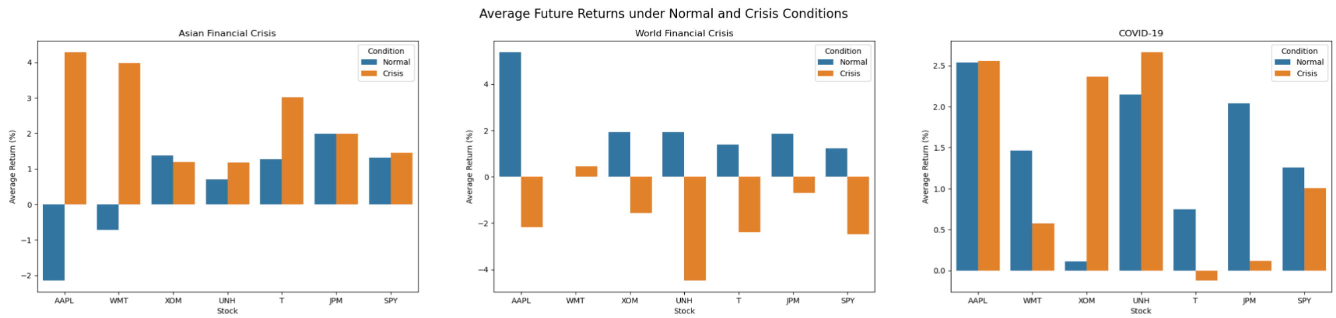
Sadly though, during the notable economic downturns such as the World Financial Crisis in 2008 and the Covid-19 pandemic, the financial sector experienced a decline in performance and was surpassed by sectors like technology, energy, healthcare, and retail. These shifts in sector dynamics during times of crisis can be attributed to specific circumstances unique to each sector. For example, the energy sector often witnesses increased demand for alternative energy sources during times of global uncertainty, while the healthcare sector experiences heightened demand for medical services and products. Additionally, the retail sector benefits from shifts in consumer behavior, such as the surge in online shopping witnessed during periods of lockdown and restricted mobility.

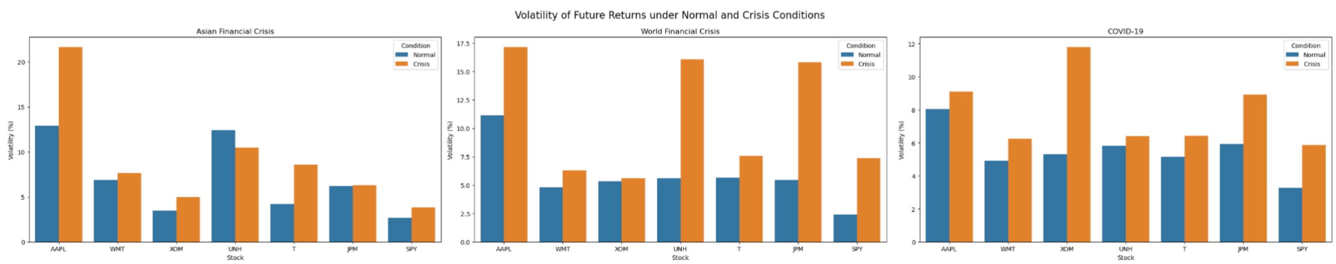


By scrutinizing the graphical representation of cumulative returns over the years, we can observe the significant rise of the technology sector and its consistent dominance in cumulative returns. However, it is important to acknowledge the impact of the stock market bubble burst during the Covid-19 pandemic, which can be attributed to the volatility of cryptocurrencies. This event resulted in one of the most substantial crashes in recent history, reverberating throughout the entire technology sector.

Average Future Returns and Volatilities

This simulation depicts the average future (5 year) returns and volatilities under both ‘Normal’ and ‘Crisis’ conditions for the 6 selected stocks and the S&P 500 Index. We defined the ‘Normal’ timeframe as 4 years before the crisis occurred as that was when economic conditions were the most stable while volatility was calculated based on standard deviation of the returns. The simulated average future returns for the Asian Financial Crisis saw Apple, Walmart, and AT&T greatly outperforming in a ‘Crisis’ compared to a ‘Normal’ condition. Apple also had the highest volatility of future returns for the Asian Financial Crisis.





For the simulated future returns for the World Financial Crisis, every stock apart from Walmart greatly underperformed under ‘Crisis’ conditions compared to ‘Normal’ conditions. The reason for the difference between the performance of stocks based on conditions from the Asian Financial Crisis and World Financial Crisis could be that the US was not as affected by the Asian Financial Crisis than it was by the World Financial Crisis. Since all the stocks are US based companies, the Asian Financial Crisis could potentially have had no impact on the finances and performance of those companies. Apple, UnitedHealth Group and JP Morgan had the highest volatilities of future returns for the World Financial Crisis. On the other hand, the World Financial Crisis had a major impact on the US stock market and hence, the respective US stocks were negatively affected and almost all of them had a negative simulated average future return under ‘Crisis’ conditions.

For the Covid-19 pandemic, Apple, Exxon Mobil, and UnitedHealth Group had the highest simulated average future returns. The reason why XOM performed so well could be due to the Russia-Ukraine war which led to the shortage in oil that caused oil prices to spike. UnitedHealth Group benefited from the pandemic as people started investing more in the Healthcare industry due to the development of vaccines and treatments.

Portfolio Optimization

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Are you looking at a Normal period or Crisis period?
Normal
How much risk are you willing to take on on a scale of 0 - 50
 (0 being no risk at all and 50 being a lot of risk)?
30
              0
AAPL   0.959779
WMT    0.000002
XOM    8.114777
UNH    0.000002
T      0.000001
JPM   90.925438
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This portfolio optimizer aims to minimize the negative sharpe ratio of the portfolio while maximizing returns by using the simulated average future returns and volatilities generated previously.. In other words, it is minimizing risk while maximizing returns. As there is no defined range for a person's risk tolerance, we came up with our own scale, based on our code, of 0 to 50 where 0 means the user is not willing to take on any risk at all and 50 means the user is willing to take on as much risk as possible. The portfolio is made up of our 6 selected stocks across different sectors in order to reduce portfolio risk. Based on one's risk-tolerance and whether they are looking at a 'Normal' or 'Crisis' period, the portfolio optimizer will generate the optimal weights the user should have for each of the 6 stocks in their portfolio. For example, when looking at a 'Normal' period and assuming a risk-tolerance level of 30, we should have approximately 1% of our portfolio in Apple stocks, 8% in Exxon Mobil stocks, and 90% in JP Morgan stocks.

Conclusion

The primary objective of this project was to conduct an in-depth examination of the effects global crises have on the U.S stock market. This involved a comprehensive analysis of how specific sectors and essential stocks behaved under these challenging conditions. The approach used for this study was multi-faceted, designed to give a broad, well-rounded understanding of market dynamics. The insights derived from this study can significantly shape investment strategies, particularly during periods of financial instability.

In this study, regression analysis was utilized to uncover the relationships between the performance of selected stocks and the S&P 500 index. This technique demonstrated that certain stocks, notably Apple, showed a strong ability to withstand market disturbances, maintaining growth despite adverse conditions. This resilience was further reinforced by examining cumulative returns, which highlighted the ascent of Apple and the technology sector as a whole even amidst general stock market turbulence. However, it is important to note that the technology sector was not the only one to exhibit resilience. The sectors of finance, energy, healthcare, and retail also demonstrated significant strength during certain crises. This evidence underscores the importance of diversification in investments across various types of securities and sectors.

Simulations were also utilized to forecast average future returns and volatilities. These simulations served to illustrate the risk-return trade-off inherent in investments. Despite the insightful nature of these simulations, investors are cautioned against using them as definitive predictors due to the inherently unpredictable nature of financial markets. Another limitation of this analysis is its inability to fully incorporate exogenous factors, such as wars or oil price shocks. While these events are accounted for in the numerical historical data used, they still represent unexpected variables that can drastically affect market performance. Future potential exogenous factors are difficult, if not impossible, to predict and account for.

In conclusion, a detailed analysis of past market performance during crises, coupled with the use of statistical models to project potential future scenarios, can equip investors with the tools necessary to devise more informed investment strategies. The optimization of a portfolio, tailored to market conditions and an individual's risk tolerance, is a beneficial approach. However, due to the unpredictable nature of financial markets, continuous research is essential. Such research serves to strengthen the role of data-driven decision-making in finance and aids investors in navigating the often turbulent world of financial investment.

Author Contributions

Theethat

- ★ Helped the group with contributing to the suggestion of analyzing the US stock markets.
- ★ Worked on the code for the regression plots and put together most parts of the poster presented in the data science fair.
- ★ Contributed in the report by writing the abstract, parts of the introduction, data sources sections, and parts of the analysis and conclusion.

Jamie

- ★ Wrote the code for the sections on simulating average future returns, and Portfolio Optimization.
- ★ Helped to format the group's code into an Object-Oriented Programming format after everyone was done.
- ★ Contributed to the writing of the report by writing the sections on Introduction, Data Sources and Methods, Analysis, and conclusions in the report.

Chan

- ★ Contributed to the code on Cumulative Returns across sectors for each Criss Period and overall returns by each sector.
- ★ Her tasks included visualizing the returns, conducting a detailed analysis and writing the conclusion along with the data sources and methods section in the report.
- ★ Peer-edited her teammate's work, compiled the report, and completed the citations.

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