Introduction

Statement of the project's purpose:

1) To identify the crisis periods
2) To calculate the stock correlations
3) To calculate CAPM Betas

Research Question

- Primary question: Does "correlation go to one" during financial crises, and is there a similar pattern for Capital Asset Pricing Model (CAPM) betas?

Scope of the Project

1) **Data used:** Daily returns for the current stocks in the S&P 500 from 1980 through 2023, including daily closes for the S&P 500 from 1927 through 2023.
2) **Definition of a crisis for the analysis, involving bear markets and subsequent bull markets.**
3) **Additional considerations such as drawdowns and recent run-ups, and different time windows (monthly, quarterly) for analysis.**

Methodology

1) Calculation of return statistics, correlations, and CAPM betas.
2) Use of statistical tests (e.g., T-test) to validate findings.
3) Discussion on the choice of summary statistics and formulas used for analysis.
4) Discussion of the tools and technologies used (Python, pandas-datareader, yfinance, etc.).
5) Reflections on the strengths and weaknesses of the analytical approach, including potential biases or limitations.

Crisis Periods:

	Crisis Start	Crisis End
0	1982-02-22	1982-09-14
1	1987-10-19	1988-03-08
2	2001-03-12	2001-12-05
3	2002-07-10	2002-08-22
4	2008-07-09	2008-12-08
5	2009-02-23	2009-03-23
6	2020-03-12	2020-04-08
7	2022-06-13	2023-06-08

Analysis:

- Peaks and troughs in S&P 500 index identified to mark transitions into bear and bull markets respectively, crucial for defining financial crises.

- Classification based on conventional analysis principles with bear markets characterized by 20% declines from highs and bull markets by 20% increases from lows.

- Identification of crisis points enables benchmarking, facilitating focused analysis of market behavior during stress periods.

- Allows for comparative analysis of market phases, offering insights into stock correlations and CAPM betas.

Historical Context of S&P 500 Milestones

- S&P 500 milestones offer insights into market dynamics, reflecting economic growth and investor sentiment.

- Significant highs include dot-com bubble peak, pre-financial crisis peak, post-crisis bull market, and COVID-19 pandemic peak.

- Dramatic lows, like during the 2008 financial crisis, and milestone changes, such as Black Monday in 1987, signal market volatility and economic impacts.

- Notable low: March 9, 2009, during the financial crisis, closing at 676.53.

- Market volatility evident in events like Black Monday in 1987 and the S&P 500's worst yearly percentage loss in 2008.

- COVID-19 onset marked by a 9.5% drop on March 16, 2020, signaling the start of a bear market.

- Market resilience shown in recovery patterns, such as a 20% increase from bear market low on October 12, 2022, to June 8, 2023, indicating the end of that bear market.

PEAKS:

|	PEAK DATE	PEAK PRICE
0	1980-11-28	140.520004

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1 1987-08-25  336.769989
2 2000-03-24  1527.459961
3 2002-01-04  1172.510010
4 2007-10-09  1565.150024
5 2009-01-06  934.700012
6 2020-02-19  3386.149902
7 2022-01-03  4796.560059
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TROUGHS:

	TROUGH DATE	TROUGH PRICE
0	1982-08-12	102.419998
1	1987-12-04	223.919998
2	2001-09-21	965.799988
3	2002-07-23	797.700012
4	2008-11-20	752.440002
5	2009-03-09	676.530029
6	2020-03-23	2237.399902
7	2022-10-12	3577.030029

Analysis:

- Dot-com bubble peak in March 2000 preceded a technology-driven market collapse, while September 11, 2001, brought global declines due to economic impact and uncertainty.

- 2007–2009 featured severe U.S. bear markets post-Chinese stock bubble, with over 50% declines in major indices, spurred by financial crisis and failures of large financial institutions.

- Flash Crash of 2010 and brief bear market in August 2011 highlighted market instability despite flat year-end.

- 2015-2016: Chinese stock market crash and global selloff; 2018: steep S&P 500 decline exposed vulnerabilities in global financial system.

- 2020 stock market crash, driven by COVID-19, led to a 34% decline from February to March, reflecting deep uncertainty and economic impact of pandemic lockdowns.

- 2022 saw a significant decline, with a 27.55% drop by October, influenced by various factors including falls in DJIA and Nasdaq Composite indices.

S&P 500 Peaks and Troughs
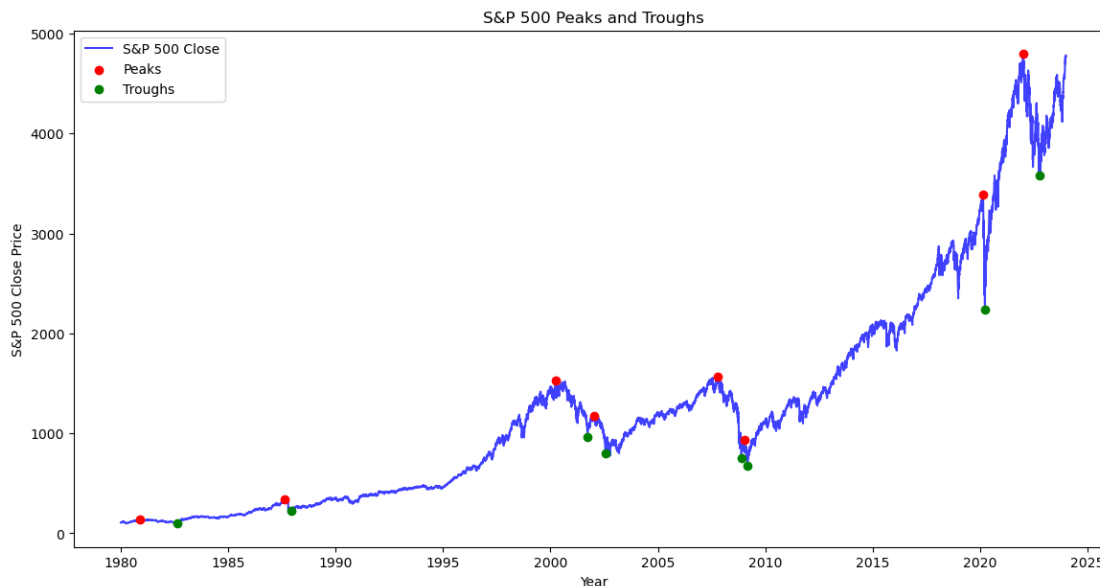
Analysis:

- S&P 500 Close Plot: Line graph shows closing prices since 1980; blue line with alpha transparency highlights trend, allowing overlaid points visibility.

- Peaks and Troughs Scatter Plot: Red points denote peaks, green points denote troughs, visually emphasizing market highs and lows, corresponding to economic optimism or recessions.

- Significant highs align with periods like late 1990s tech bubble and mid-2000s housing boom; lows relate to early 2000s recession, 2008 financial crisis, and COVID-19 pandemic.

- Notable market moments: Dot-com bubble peak in 2000, subsequent early 2000s low; 2007 peak before global financial crisis, 2009 trough marking market bottom; significant drop in early 2020 reflecting COVID-19 impact.

- 2023 rally driven by mega-cap stocks ("Magnificent Seven") like Amazon, Apple, Tesla, contributing to strong index performance; however, 72% of stocks underperformed.

- Goldman Sachs predicted economy to avoid recession in 2023, which held true; forecasts for 2024 suggest more moderate S&P 500 returns, with 5-10% range, indicating cautiously optimistic outlook.

(	BEAR MARKET START	BEAR MARKET END
0	1982-02-22	1982-09-14
1	1987-10-19	1988-03-08
2	2001-03-12	2001-12-05
3	2002-07-10	2002-08-22
4	2008-07-09	2008-12-08
5	2009-02-23	2009-03-23
6	2020-03-12	2020-04-08
7	2022-06-13	2023-06-08,
	BULL MARKET START	BULL MARKET END
0	1982-09-14	1987-10-16
1	1988-03-08	2001-03-09
2	2001-12-05	2002-07-09
3	2002-08-22	2008-07-08

4	2008-12-08	2009-02-20
5	2009-03-23	2020-03-11
6	2020-04-08	2022-06-10
7	2023-06-08	2023-12-29)

Analysis:

- Bear markets: Index drops by 20% or more triggering start date storage until 20% recovery from trough marks end date.

- Bull markets: Characterized by rising investor confidence, economic recovery, sustained stock price increases, lasting until another bear market is identified.

- Importance: Crucial for investment strategies, risk management, setting market volatility expectations.

- Historical trends: Bull markets follow significant downturns, like post-2008 financial crisis and COVID-19 pandemic, leading to new record highs.

- Tracking: Sophisticated approach identifies start/end points, categorizing market cycles based on natural oscillations between optimism and pessimism.

- S&P 500: Historically rises in 12 months following new bull market onset, averaging 19% one-year return.

- Resilience: Bull markets face initial challenges but tend to be resilient over the long term, as seen in mid-2023 S&P 500 rally despite economic concerns.

- Caution: Past performance not indicative of future results, each cycle influenced by contemporary economic conditions, sentiment, and global events.

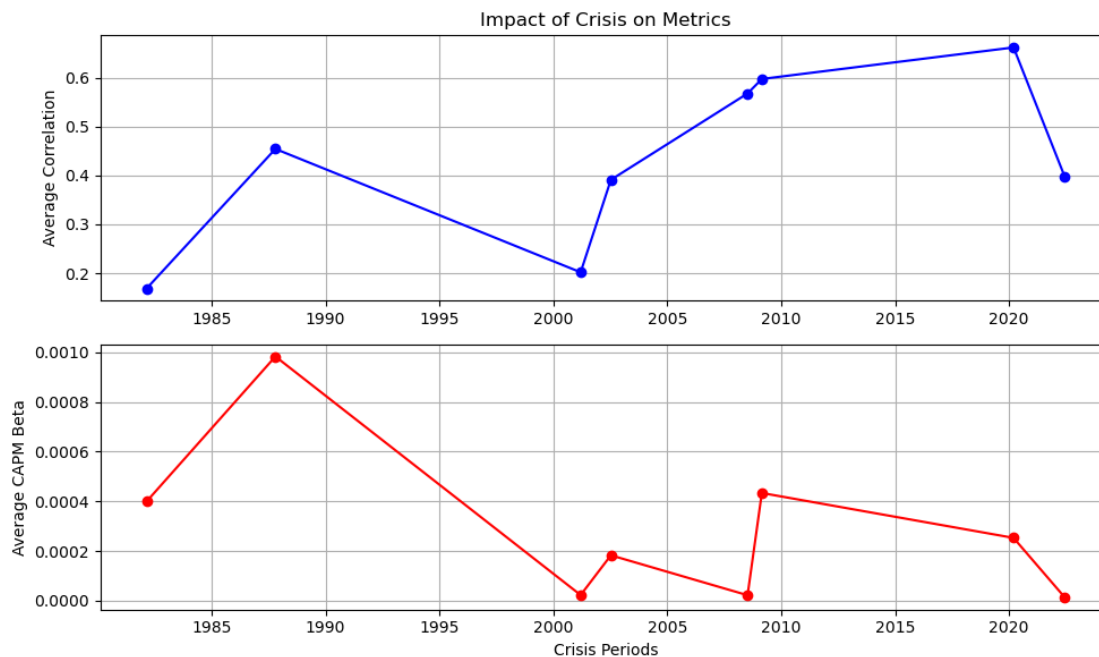## Correlation and CAPM Beta Calculation:

- Correlation analysis: Computes Pearson correlation coefficient between individual stock returns and overall market returns for both crisis and non-crisis periods.

- CAPM Betas: Utilizes calculate_capm_betas function to determine beta values for individual stocks, measuring their volatility relative to the market.

- Historical context: S&P 500 performance during major market crashes showcases recurring events with varying recovery times:

  - Great Crash of 1929: Nearly 25 years for full recovery.

  - Black Monday crash of 1987: Recovery in just 19 months.

  - Dot Com Bubble (2000): Approximately 86 months for recovery.

  - Global Financial Crisis (2007-2008): Recovery lasting about 65 months.

  - COVID-19 crash (2020): S&P 500 dropped by 34%, swift reversal aided by historic fiscal stimulus and Federal Reserve financing.

- Market disconnect: Despite steep market rally post-COVID-19 crash, Great Depression-level unemployment figures highlight disparity between stock market and broader economy.

- Insights for investors and analysts: Understanding historical reactions of S&P 500 during crises provides insights into potential unfolding and speed of market recoveries, aiding in decision-making processes.

Correlation Matrix During Crisis

Correlation Matrix During Non-Crisis

Comparison of Average Correlation and CAPM Beta during Crisis and Non-Crisis Periods
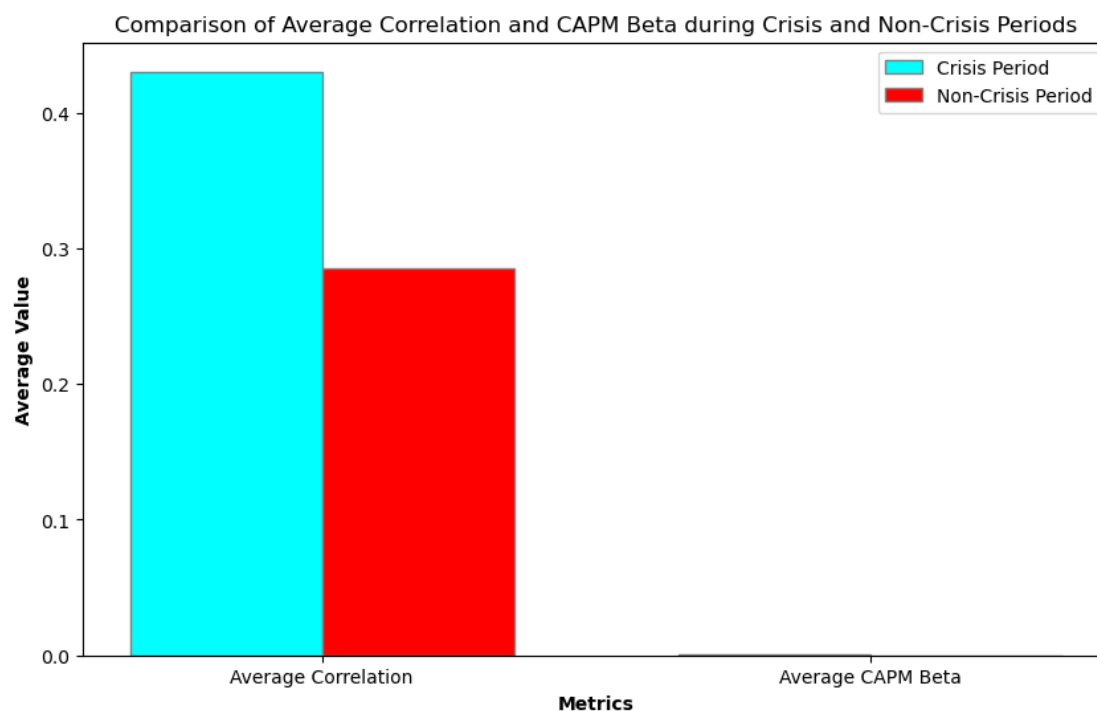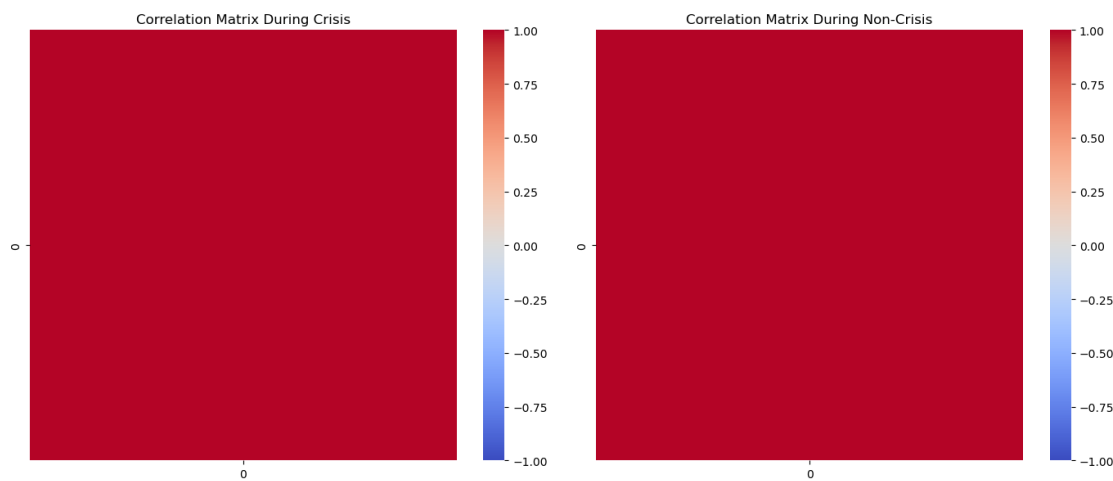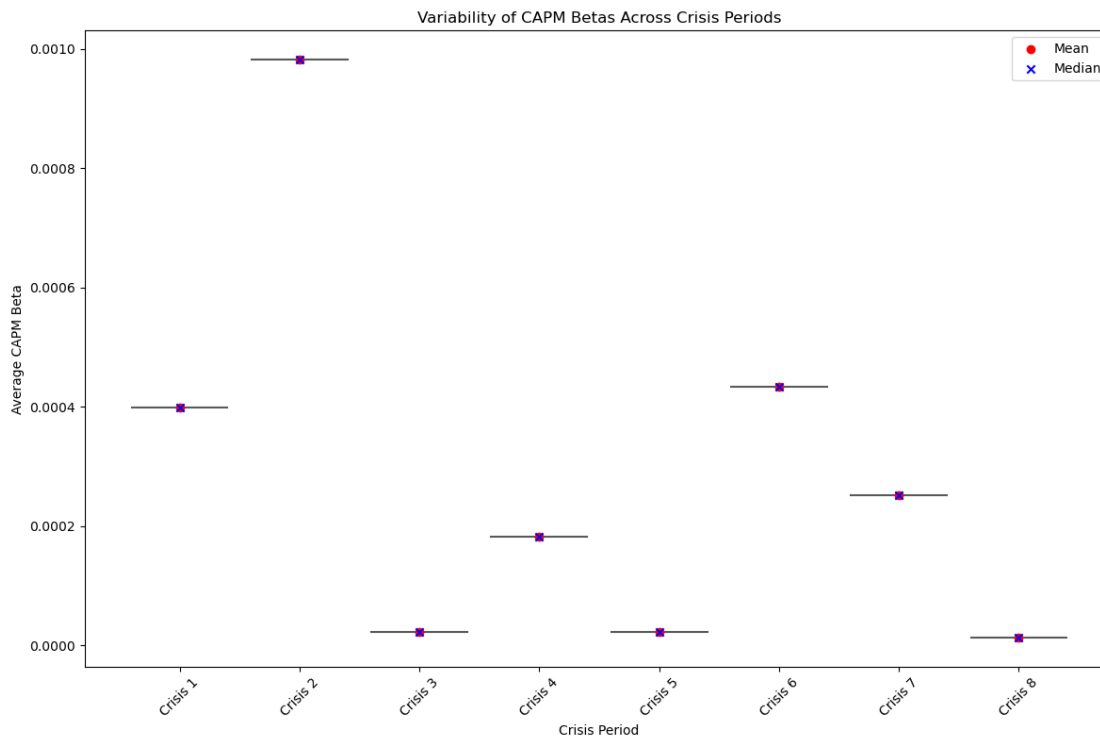
Analysis:

- Heatmaps: Visual representations of correlation matrices, with colors indicating strength and direction of correlations (red for high positive, blue for high negative).

- Crisis period heatmap: Reflects correlations during economic stress, showing how variables move together or in opposite directions.

- Non-Crisis period heatmap: Allows comparison to understand changes in relationships between variables under stable economic conditions.

- Importance of comparison: Helps analysts draw conclusions about stability of relationships between financial metrics during different economic states.

- Bar chart: Communicates average values of metrics for crisis and non-crisis periods, facilitating immediate visual comparison.

- Interpretation of bar chart: Higher cyan bar for 'Average Correlation' suggests higher systemic risk during crises, while higher cyan bar for 'Average CAPM Beta' indicates increased asset volatility.

- Significance of findings: Highlights increased systemic correlations and higher asset volatility during economic downturns, aligning with academic research.

- Role of correlation matrices in financial crises: During market crashes, stocks tend to behave similarly, while bubble periods accentuate sector disparities, leading to higher average correlations.

- Importance of copulas: Help in understanding joint distribution of multiple assets during financial downturns, particularly relevant for managing tail-dependence.

- Eigen-entropy and stability of financial networks: Advanced method for assessing market volatility and systemic risk, with large eigenvalues in correlation matrices indicating intense correlation presence and potential market-wide impacts during crises.
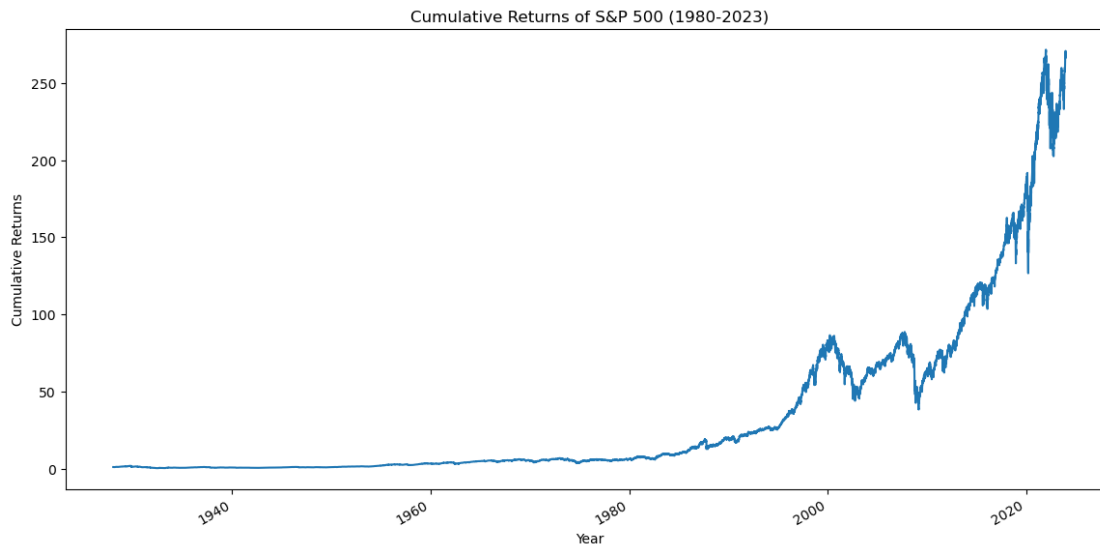

Analysis:

- Line plots: Display changes in 'Average Correlation' and 'Average CAPM Beta' over multiple crisis periods.

- 'Average Correlation' (blue line): Shows significant variability, with notable increases during specific crisis periods, indicating closer stock movements during turbulent times.

- 'Average CAPM Beta' (red line): Demonstrates varying values, typically peaking during crisis periods, suggesting increased systemic risk and volatility compared to the broader market.

- Interpretation during crises: Increased correlations suggest similar reactions to broad market shocks, while beta values indicate individual stock or sector sensitivity to market-wide movements.

- Impact of COVID-19 crisis: Companies, especially in sectors like technology and pharmaceuticals, experienced significant changes in betas, indicating shifts in stock responsiveness to the market.

- Work-from-home (WFH) companies: Experienced decreased beta, signaling an inversion in risk-return relationship and prompting a reevaluation of portfolio rebalancing strategies in the "topsy-turvy" environment.

Variability of CAPM Betas Across Crisis Periods

Analysis:

- Violin plot: Visualizes distribution and probability density of 'Average CAPM Beta' across different crises.

- Width of plot: Corresponds to density of data, with wider sections indicating higher frequency of data points.

- Variability in distributions: Some crises show wider distributions of CAPM betas, indicating significant divergence in how individual stocks were affected by market conditions.

- Interpretation: Thicker parts represent higher probability of data points falling within that region, while thinner parts indicate lower probability.

- Value in financial data analysis: Useful for comparing distributions of returns or other metrics across different time periods or conditions, such as pre- and post-crisis.

- Example: Comparing CAPM beta values across various crises reveals concentration of data and commonality of certain beta values within each crisis period. Wider distributions during some crises suggest greater variability in individual stock responses to market movements.

Cumulative Returns of S&P 500 (1980-2023)

Analysis:

- Plot description: Illustrates cumulative returns of S&P 500 from 1980 to 2023, showcasing long-term upward trend and significant growth over decades.

- Purpose: Commonly used to visually represent investment performance over time, offering insight into overall direction and magnitude of growth beyond raw numbers.

- Cumulative return definition: Total change in investment value over a period, providing context on investment performance.

- Considerations: Cumulative returns may give impression of older investments being more impressive due to higher cumulative values over time.

- Potential for misleading comparisons: Without accounting for differences in investment start times, comparisons based solely on cumulative returns may be misleading.


CAGR of S&P 500 (1980-2023): 6.03%
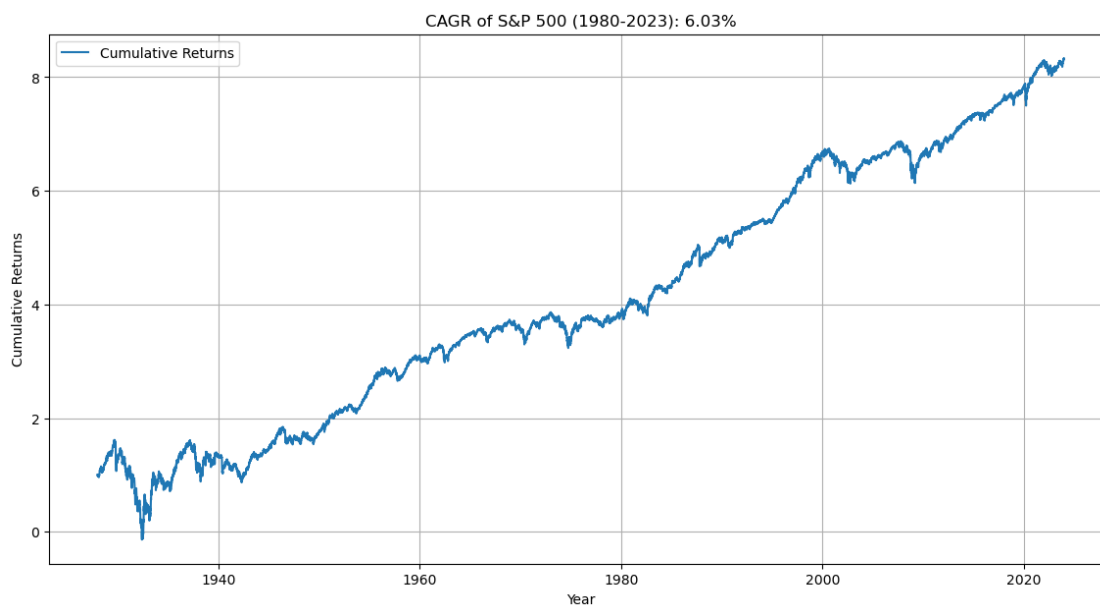
The plot demonstrates the calculation of the compound annual growth rate (CAGR) for the S&P 500 over the same period. CAGR provides a smoothed annual rate of growth, which can be more informative than simple cumulative returns, especially for comparing different investments.

Monthly Average Correlation of S&P 500 Stocks with Crisis Periods Highlighted
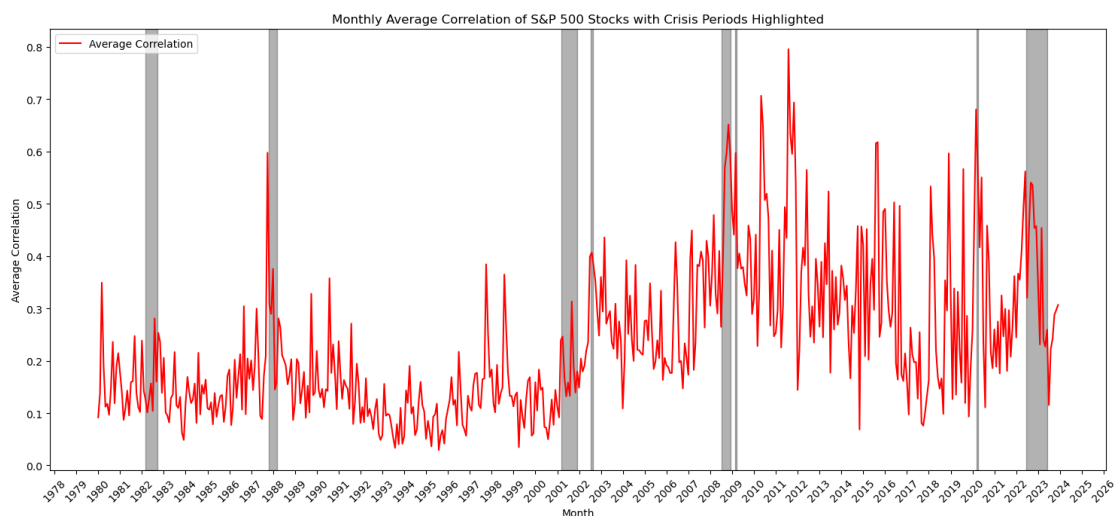
Analysis:

- Graph significance: Instrumental in illustrating fluctuations in average stock correlations within the S&P 500 over time, especially during financial crises.

- Crisis periods: Highlighted periods indicate significant rises in stock correlations, reflecting "flight-to-quality" and "risk-off" market behaviors during global economic shocks.

- Impact on diversification: Higher correlations during crises erode diversification benefits, making risk mitigation more challenging.

- Market dynamics: Correlations between stocks typically increase during market stress, attributed to investors' collective response to uncertainty, leading to simultaneous selling or buying across different asset classes.

- Major events between 2010 and 2021: European sovereign debt crisis (2010), U.S. bear market (2011), Chinese stock market crash (2015-2016), Dow Jones decline (2015), COVID-19 pandemic (2020).

- Investor behavior during crises: Risk-off behavior drives up correlations between stocks as investors move away from equities towards safer assets.

- COVID-19 pandemic: Triggered rapid and severe stock market crash in 2020, leading to economic standstill and uncertainty, potentially increasing stock correlations.

- Sensitivity to macroeconomic shocks: Spikes in correlation during crisis years highlight markets' sensitivity to systemic risks and macroeconomic shocks, leading to simultaneous global sell-offs.

S&P 500 Daily Close with Highlighted Crisis Periods
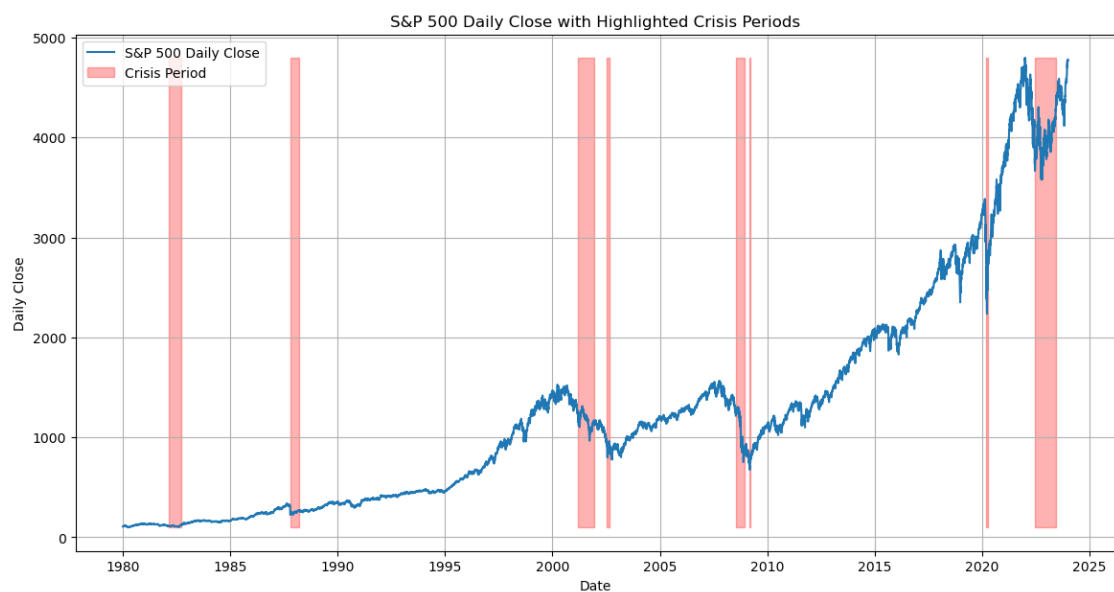
Analysis:

- Visualization significance: Indicates S&P 500 response during economic shocks, with red shaded areas representing crisis periods coinciding with significant volatility and index declines.

- Historical sensitivity: S&P 500, like other major indices, shows sensitivity to crises such as the Global Financial Crisis (GFC) and COVID-19 pandemic, experiencing sharp declines in value and heightened volatility.

- Uneven recovery: During COVID-19 pandemic, S&P 500 initially fell sharply before recovering unevenly, highlighting differential sector impacts.

- Interconnectedness of global markets: Crises reinforce global market interconnectedness, intensifying risk transmissions and volatility spillovers across assets and indices.

- Role of commodities: Gold exhibits safe haven characteristics during economic uncertainty, while assets like oil can experience increased volatility, diversification strategies incorporating commodities aid in risk minimization.

- T-statistic interpretation: Measures deviation from null hypothesis' assumed population mean, with high absolute values and low p-values rejecting null hypothesis.

- Significant differences: Results show significant differences in correlations and CAPM betas between crisis and non-crisis periods, indicating higher correlations and variable risk profiles during crises.

- Correlation interpretation: Used to quantify strength and direction of linear relationship between variables, but does not imply causation and may not account for extraneous variables.

- Interpretation caution: Statistical tests provide evidence of association, not causation; influence of variables or external factors cannot be conclusively determined from correlations alone.
- Beta consideration: Historical measure, not guaranteed predictor of future performance, important to recognize in financial analysis.

Average Correlation:

For each crisis, the t-statistics are significantly negative, and the p-values are 0.0. This suggests a higher average correlation during crisis periods compared to non-crisis periods. In simpler terms, during crises, stocks move more similarly than they do in calmer times, which could impact diversification strategies negatively.

Monthly Average CAPM Betas of S&P 500 Stocks with Crisis Periods Highlighted
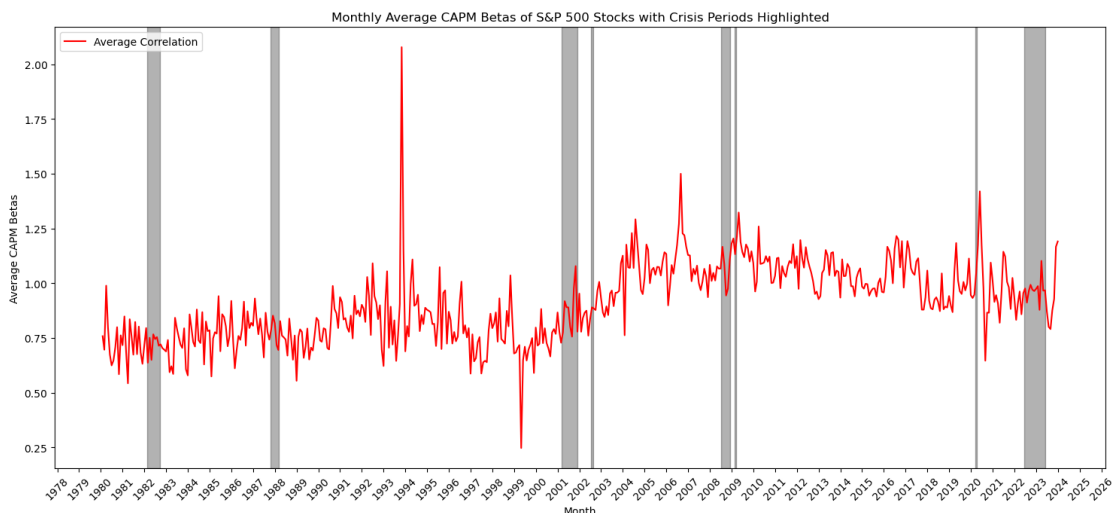
Analysis:

- Plot description: Red line represents average CAPM beta per month, shaded gray areas indicate crisis periods.

- Beta interpretation: Higher beta suggests higher returns due to higher risk, lower beta indicates lower risk and potentially lower returns.

- Fluctuations: Observations of beta fluctuations across different times, with spikes often seen during crisis periods indicating increased systemic risk and volatility.

- Impact of financial crises: Increased market volatility and systemic risk during crises lead to higher beta values for stocks, implying greater sensitivity to market movements and increased risk.

- Investor considerations: Understanding beta changes during crises influences investment decisions regarding risk and return, prompting adjustments such as adding stable, low-beta stocks to mitigate risk.

- Portfolio management perspective: Highlighting crisis periods in beta analysis aids in identifying shifts in market risk profile, guiding adjustments in asset allocation to maintain desired risk levels and emphasizing dynamic risk assessment strategies.

- Spike in 1993: Associated with economic and political events, including the European Exchange Rate Mechanism (ERM) crisis, official creation of the European single market, and changes in interest rates by major banks like the Bank of England, impacting market dynamics and investor perception of risk.

Final Conclusion

The observed spikes in correlation approaching 1 during non-crisis periods suggest that high correlation between stocks is not exclusively a phenomenon of crisis periods. While it is true that during crises, correlations tend to increase — a concept known as "correlation breakdown," where diversified portfolios may converge to a correlation of 1 and thus move in tandem — this is not a rule that applies universally. Market dynamics are complex and influenced by a multitude of factors, including economic indicators, corporate earnings reports, regulatory changes, and investor sentiment, which can also lead to increased correlations outside of crises.

For example, a non-crisis event such as a major technological breakthrough in an influential sector or a regulatory change affecting a large segment of the market could result in increased stock correlations. Additionally, in a highly interconnected global economy, international events can affect markets worldwide, causing correlations to rise even during stable economic periods.

The spikes in average stock correlations observed in the image during non-crisis periods, approaching or reaching the level of 1, suggest that while crises often trigger a rise in correlations, they are not the sole cause of such phenomena. In fact, high correlation levels can also occur during non-crisis times due to various factors, including macroeconomic news, sectoral shocks, or systemic changes affecting multiple industries simultaneously.

During crises, the market tends to display what is known as "flight-to-quality" and "risk-off" behaviors, where investors move towards safer assets and away from riskier ones, leading to a more pronounced co-movement of stocks, sometimes causing correlations to approach 1. However, non-crisis periods can also experience periods of heightened correlation due to, for example, collective reactions to technological changes, regulatory reforms, or significant shifts in monetary policy. These events can affect investor sentiment and behaviors across the board, leading to similar buying or selling trends and hence higher correlations

The strong statistical evidence from the t-tests confirms that crises have a notable impact on market dynamics, causing stocks to move more in unison, which can erode the benefits of portfolio diversification.

The t-test results for average correlation and average CAPM Beta over various crises reveal a compelling narrative about the behavior of the S&P 500 during these tumultuous times.

For average correlation, the highly negative t-statistics during certain crises (Crisis 1 and Crisis 3, for example) with p-values at 0.0 indicate a statistically significant increase in stock correlation during these periods. In contrast, positive t-statistics (Crisis 2, 4, 5, 6, and 7) with p-values at 0.0 suggest instances where correlation might have been high but not necessarily as uniform across the board. This divergence in correlation behavior underscores the unique nature of each

crisis — while all are periods of increased stress, the market's response in terms of stock correlations can vary widely, possibly reflecting the specific causes and conditions of each crisis.

The CAPM Beta results offer insights into market volatility and systematic risk. For most crises, positive t-statistics with extremely low p-values suggest that the market experienced higher volatility during these periods. Notably, Crisis 1, 2, 4, 6, and 7 showed significantly higher betas, indicating that stocks were more reactive to market swings and thus, carried higher risk. On the other hand, a negative t-statistic for Crisis 3, 5, and 8 with p-values indicating significance (except for Crisis 3 which was not significant) suggests periods where the systematic risk was different from the market, potentially less reactive to market swings.

The statistical evidence, underscored by the t-test results, affirms that during crisis periods, the average stock correlations within the S&P 500 show a marked tendency to increase, often approaching 1. This convergence toward 1 during crises illustrates the market phenomenon where individual securities' price movements become highly interdependent. In such scenarios, the typical benefits of diversification may be diminished, as stocks move more in lockstep in response to prevailing economic stressors, rather than according to individual company performance or sector-specific trends.