Data Wrangling - Project Report: How Central Bank Interest Rates Affect the Major Stock Market

Aldric de Jacquelin

Research question & Introduction :
Changes in the interest rate by the central bank have a wide range of impact on the international financial market. By decreasing the interest rates, central banks can stimulate spending by making borrowing money cheaper. Conversely, an increase in interest rate can make borrowing more expensive, potentially slowing down the economy. This mechanism is used to control the inflation within the economy which in turn affects exchange rates, unemployment as well as the stock and bond markets. This report aims to answer the question on how the central banks interest rate affects the major stock market indices. To achieve this, the analysis will especially focus on the financial market of the United States. The financial market of the United States is recognized as the largest and most influential financial market in the world, with data widely available. This means that the interest rate that will be used is the interest rate set by the central bank of the United States, also known as the federal funds rate. The stock indices that we compare to this interest rate is the S&P 500. Due to its broad composition, the S&P 500 is widely regarded as a benchmark for the U.S. stock market, providing a reliable view of its development.
The main subject raised will be answered by answering the following subquestions.

What historical trends exist between central bank interest rate changes and movements in major stock market indices?

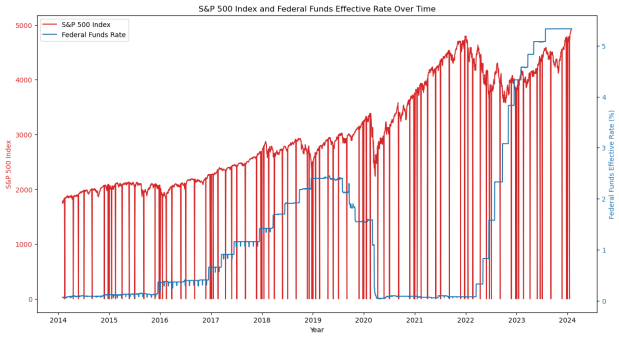

Fig. 1

According to the historical trends displayed in Figure 1, the past ten years have shown an inverse relationship between changes in interest rates in the United States—specifically the federal funds rate—and the S&P 500 stock price. When the Federal Funds Rate decreased, the S&P 500 index notably rose, especially from 2020 to 2022, when the Federal Funds Effective Rate reached its lowest point. Initially, the S&P 500 Index dropped in panic but then surged dramatically. Conversely, an increase in the federal funds rate corresponded with slower growth or even a decline in the S&P 500. After 2022, as the Federal Funds Effective Rate sharply increased, the downturn halted until the end of 2022. This phenomenon can be attributed to the lower borrowing costs when the Federal Funds Rate decreased, leading to higher consumer spending and stimulated investment. Such an environment was favorable for the stock market, resulting in a greater increase in the index.

On the other hand, an increase in the Federal Funds Rate made borrowing more expensive and saving more attractive, potentially slowing economic growth. However, this phenomenon primarily explains the short-term effects depicted in Figure 1, where interest rate hikes lead to market sell-offs and volatility. In the long run, the impact is more complex; an increase in interest rates, indicative of a strengthening economy, can justify periods in which, despite rising rates, the S&P 500 index still exhibits upward growth. For instance, during periods such as 2016 to 2019 and 2023 to 2024, even with raised Federal Fund Rates, the S&P 500 Index was not negatively impacted.

How do interest rate changes affect different sectors within the stock market (e.g., technology, finance, manufacturing)?

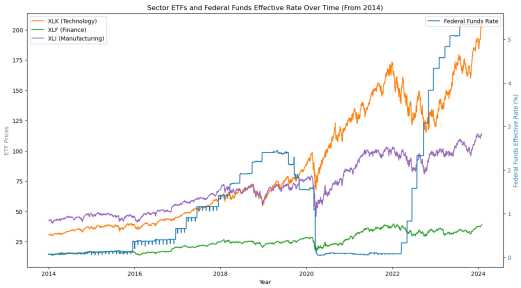

Fig. 2

Figure 2 illustrates the comparison between the Federal Funds Effective Rate and the performance of three key sector ETFs over time: XLK (Technology Sector ETF), XLF (Financial Sector ETF), and XLI (Manufacturing Sector ETF). An inverse relationship is observed where an increase in interest rates leads to a decrease in ETF prices across all sectors. However, the sensitivity of these ETFs to interest rate changes varies by sector. This was particularly evident from 2020 to 2022, during which a sharp decrease in the Federal Funds Rate resulted in an increase in ETF prices for all sectors. The technology sector, represented by the yellow line, surged after initially plummeting due to panic. The manufacturing sector experienced a smaller increase, yet both were more substantial than the increase in the financial sector. Overall, the technology sector exhibited the highest ETF prices and volatility, the manufacturing sector was less volatile, and the financial sector was the most stable but had the lowest ETF prices. Figure 3 illustrates the correlation between the Federal Funds Rate and different market sectors. Technology stocks, characterized by their potential for growth over immediate earnings, show a marked sensitivity to interest rate fluctuations. Despite the high ETF prices within the technology sector, Figure 3.1 reveals a complex interaction with interest rate changes, a mixed pattern of correlation and divergence. This complexity suggests that factors such as technological innovation and market demand might play a more significant role in influencing stock prices than interest rate adjustments alone. The manufacturing sector, while also volatile, displays periods of inverse correlation with the Federal Funds Rate, underscoring the influence of microeconomic elements beyond mere interest rate effects. In contrast, the finance sector demonstrates a clearer inverse relationship with the Federal Funds Rate. This is attributed to the direct impact of interest rate changes on banks and financial institutions, influencing key financial mechanisms

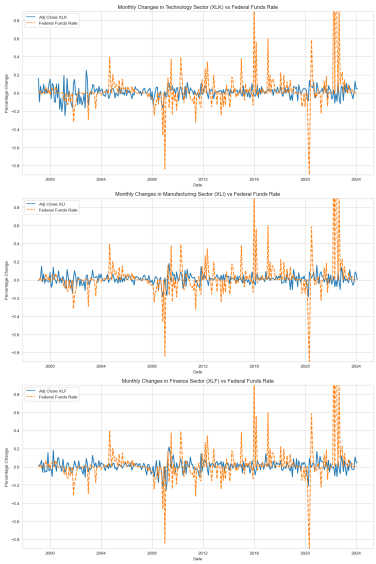

Fig. 3

like loan interest rates, borrowing costs, and bond prices.

Are the impacts of interest rate changes on stock market indices more pronounced in the short-term or do they have significant long-term effects as well?

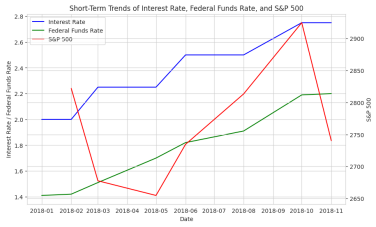

Fig. 4

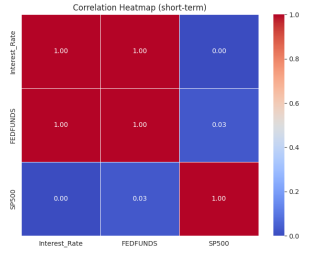

Fig. 5

Figure 4 and 5 examine the relationship between interest rate changes, particularly the Federal Funds Rate, and short-term movements in the S&P 500 stock market index. Through analysis, it has been observed that the S&P 500 exhibits more drastic fluctuations in the short term, with sudden drops coinciding with interest rate increases. Despite these initial declines, the index tends to recover and continue its upward trajectory even as interest rates continue to rise. However, the index dropped again at the end of 2018. Regarding long-term trends, focusing on the period from 2014 to 2019, it is observed that the S&P 500 exhibited a positive correlation with interest rates during this period in Figure 6 and 7. Specifically, as interest rates rose from 2014 to 2019, the S&P 500 experienced steady growth. Conversely, when interest rates declined, the S&P 500 saw significant increases. Although interest rate changes have both short-term and long-term effects, short-term movements may exhibit more heightened volatility in response to interest rate changes. In the long-term perspective, there are more factors having an impact on stock performance.

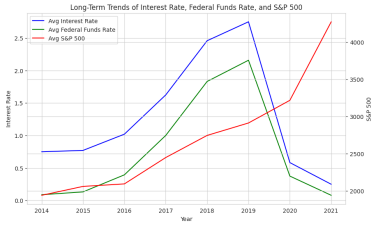

Fig. 6

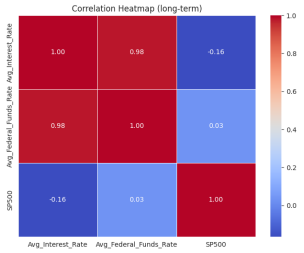

Fig. 7

How does the impact of interest rate changes on stock markets compare with the effects of other major economic indicators ?

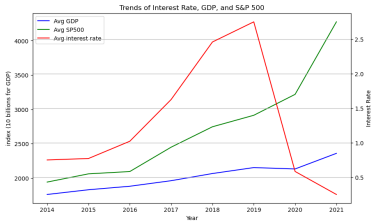

Fig. 8

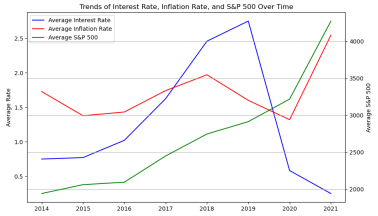

Fig. 9

Figure 8 and 9 show that interest rates are rising while S&P 500 is also increasing from 2014 to 2019. This is a scenario where the traditional relationship between interest rates and stock market performance is not being followed, which suggests that other factors may be influencing the stock market more prominently. The reason may be that rising GDP leads to increased production, consumption, and investment, which can translate into higher corporate profits and rising stock prices. However, when interest rates started to drop, S&P 500 increased drastically, which shows interest changes could have an impact on S&P 500. Overall, while rising interest rates traditionally exert downward pressure on stock prices, the observed increase in both interest rates and the S&P 500 suggests that other factors, such as strong

GDP growth may be driving stock market performance. On the other hand, Figure 9 shows that the S&P 500 index continues to rise despite a rise in the inflation rate. This suggests that the relationship between inflation and stock market performance may not be as significant compared to interest rate.

A study case: How do fluctuations in the S&P 500 correlate with major currency pairs in the forex market, especially during periods of significant interest rate changes by the U.S. Federal Reserve?

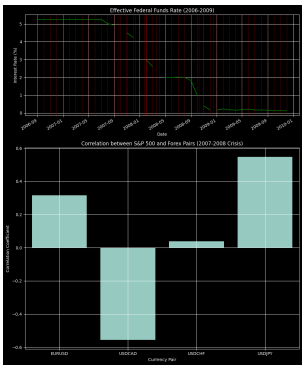

Fig. 10

I.Correlation Analysis between S&P 500 and Major Forex Pairs around Rate Cuts: we aim to analyze how the S&P 500 index's movements correlate with major currency pairs (EURUSD, USDCAD, USDCHF, USDJPY) around the dates of interest rate changes by the Fed during the 2007-2008 crisis. Figure 10 illustrates the effective Federal Funds Rate from 2006 to 2009, showing a sharp decline consistent with the Federal Reserve's aggressive rate cuts during the financial crisis. Vertical red dashed lines indicate significant policy changes or economic events. The accompanying bar chart reveals the correlation between the S&P 500 and four major currency pairs (EURUSD, USDCAD, USDCHF, USDJPY) throughout the 2007-2008 crisis. EURUSD and USDJPY exhibit a positive correlation with the S&P 500, suggesting a stronger relationship with its movements than the negatively correlated USDCAD and USDCHF. Figure 13 depicts the normalized price movements of the S&P 500

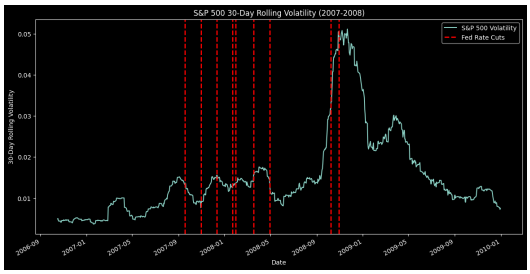

Fig. 11. Impact of Fed Rate Cuts on S&P 500 Volatility: to assess how the S&P 500's volatility responded to Fed's rate cuts during the crisis period

and the aforementioned forex pairs between 2006 and 2010, allowing comparison on the same scale despite varying absolute price levels. The data reveals a significant downturn in the S&P 500 starting in late 2007, aligning with the financial crisis timeline. Each currency pair follows a unique trajectory, with moments of parallel or inverse movements to the S&P 500. Notably, the EURUSD pair peaks as the S&P 500 declines, indicating a possible shift away from U.S. dollar assets.

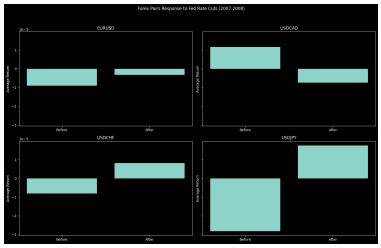

Fig. 12. Comparative analysis of Forex Pair responses to Fed rate cuts: we will compare how different forex pairs responded immediately after the Fed's rate cuts during the crisis period.

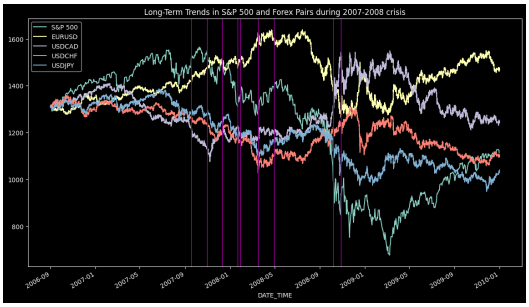

Fig. 13. Long-Term Trends and Reactions in Forex Pairs and S&P 500 During Crisis:to examine the long-term trends in the S&P 500 and major forex pairs during the crisis, highlighting key Federal Reserve rate cut dates.

The USDCAD's movement reflects falling oil prices, while the Swiss Franc and Japanese Yen's trends suggest their roles as safe-haven currencies during the crisis.

These visualizations highlight the dynamic correlations between the S&P 500 and forex pairs, with varying sensitivities to economic events. The forex market's response to the crisis underscores the complexity of factors influencing currency movements, including interest rate differentials, economic data, and global risk sentiment. The period marked by clustered lines in late 2007 and 2008 corresponds to the Fed's intensive policy actions, mirrored by significant trends in the S&P 500 and divergences among forex pairs.

Post-crisis, the S&P 500 and forex pairs began to stabilize and recover, reflecting the gradual healing of the global economy and continued accommodative monetary policy. The recovery paths vary, illustrating the different paces and strengths of regional economic recoveries.

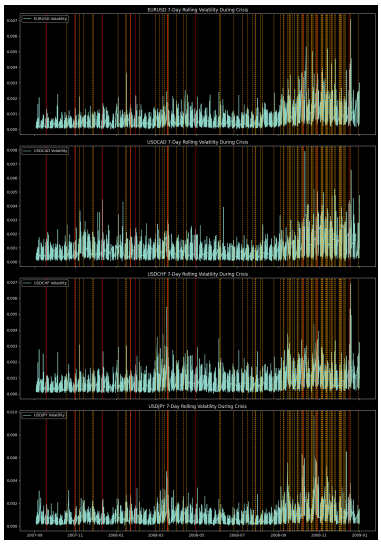

Fig. 14

II.Forex Market volatility in response to S&P 500 changes during Fed Rate Adjustments. This analysis explores the volatility of major forex pairs (EURUSD, USDCAD, USDCHF, USDJPY) in response to S&P 500 shifts triggered by U.S. Federal Reserve interest rate adjustments during the 2007-2008 financial crisis. By examining 7-day rolling volatility around Fed rate cut dates, we observe the forex market's reaction to shifts in U.S. equity influenced by monetary policy. The plots reveal volatility trends for each currency pair, with spikes indicating increased market stress or uncertainty. These spikes, especially around red vertical lines marking Fed rate cuts, highlight the forex market's sensitivity to U.S. monetary policy changes.
Additionally, orange dotted lines may correspond to other significant financial events, suggesting that multiple factors contributed to market volatility. The analysis shows varying sensitivity levels across different currency pairs to the same events, with an overall trend of increasing volatility throughout the crisis. This suggests a strong market reaction to Fed policy, impacting forex trading strategies and highlighting different exposures to U.S. economic conditions among the currency pairs.

Data sources:

interest rate America
https://fred.stlouisfed.org/series/INTDSRUSM193N
https://www.federalreserve.gov/data.htm
https://fred.stlouisfed.org/series/FEDFUNDS
https://www.kaggle.com/datasets/federalreserve/interest-rates
Stock market performance America
https://libguides.princeton.edu/econ-finance/StocksUSA
https://fred.stlouisfed.org/series/SP500
GDP, inflation rate
https://fred.stlouisfed.org/series/GDP
https://fred.stlouisfed.org/series/T5YIE
FOREX, global charts
https://www.investing.com/charts/forex-charts
https://www.alphavantage.co/documentation
https://www.kaggle.com/datasets/amin233/forex-top-currency-pairs
https://forexsb.com/historical-forex-data
S&P500 & historicals
https://www.kaggle.com/code/anitarostami/time-series-forecasting
https://finance.yahoo.com/quote/5EGSPC/chart
https://www.macrotrends.net/2324/sp-500-historical-chart-data
https://www.slickcharts.com/sp500/returns
https://ycharts.com/indicators/sp_500_annual
https://fred.stlouisfed.org/series/SP500
Sector ETFs
https://finance.yahoo.com/quote/XLK?p=XLK&.tsrc=fin-srch
https://finance.yahoo.com/quote/XLF

Data wrangling methods:

In addressing the pivotal queries regarding the interplay between central bank interest rate shifts and stock market indices, our data wrangling methodology employed a robust suite of Python techniques to extract, preprocess, and interpret the data. The initial phase involved meticulous data acquisition from CSV files, followed by the transformation of date columns into datetime objects, setting the stage for time series analysis. Through the use of Matplotlib, we crafted dual-axis time series plots that juxtaposed the S&P 500 index against the federal funds rate, visually elucidating the historical inverse relationship between these two metrics. To bolster efficiency, we automated recurrent data preparation tasks like file reading and data filtering, thereby streamlining the workflow and focusing on the substantive analysis.
For sector-specific impact assessment, we integrated advanced data manipulation tactics, including the merging of distinct datasets and resampling of time series data to a monthly cadence, weekly or daily likewise, thereby enabling month-over-month comparative analyses. The deployment of Seaborn's visualization capabilities brought to the fore the nuanced monthly fluctuations across different stock market sectors vis-à-vis interest rate adjustments.
Key to our approach was the handling of missing data and the precise alignment of datasets based on date indices, ensuring rigorous and comparable analyses. The datasets' amalgamation, resembling database-style joins, followed by the aggregation of data points to distill average annual metrics, laid a solid foundation for our subsequent analytical endeavors. The culmination of these efforts was the generation of a correlation matrix, rendered through a Seaborn heatmap, which articulated the intricate correlations between the average interest rate, Federal Funds rate, and S&P 500 values. The analytical endeavor to unravel the intricate relationship between central bank interest rate decisions and stock market indices during the 2007-2008 financial crisis epitomizes a comprehensive application of data wrangling methodologies using Python.
This methodical application of data acquisition, cleansing, integration, aggregation, and visualization not only fortified our analytical precision but also enriched our interpretative insights, shedding light on the dynamic relationships between economic policy measures and market performances.

Conclusions

This report provides an in-depth analysis on how the central bank interest influences the stock market by looking at the US federal funds rate against the S&P 500. This was done by observing historical trends, sector specific impacts, short vs long term fluctuations, the impact of other economic indicators and the interplay between the S&P 500 and major currencies.
Our analysis revealed an historical inverse relationship between interest rate adjustments and performance in the S&P 500. This underscores the pivotal role of monetary policy within financial markets. This inverse relationship extends within different sectors. The sensitivity of this relationship differs however by sector, with the finance sector showing the most clear inverse relationship. Furthermore, our findings show that changes in interest rates have a more immediate response in the stock market prices, suggesting that these changes are predominantly short term.
While adjustments in interest rate by the central bank affects the major stock market, it is not the major indicator. The stock market reacts to all kinds of variables, making it hard to predict solely on one indicator. Future research should therefore include more of these variables such as unemployment rates, political stability and other global events to gain a deeper understanding on how changing interest rates affect the stock market. Moreover, changes between 2020 and 2022 deserve a closer examination due to the strong correlation between changes in the stock market and the Covid-19 pandemic.