Financial Market Analysis: Volatility Modeling and Comparison with Hedging Instruments

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1 Introduction

In recent years, geopolitical tensions have increasingly impacted global markets, highlighting the need for strategies to mitigate related risks. Historical data show that traditional hedging tools, such as defense stocks and precious metals, have been used to protect against risks during times of geopolitical uncertainty. For example, during major crises such as the World Wars and the Cold War, defense stocks often outperformed broader market indices ([4]), while gold and silver historically have functioned as safe havens during uncertain periods ([1]). This underscores the need for investors to adapt their strategies in response to the evolving nature of geopolitical challenges. However, given the rapid advances in contemporary technology, it is reasonable to hypothesize that novel opportunities for hedging instruments may emerge.

To address this need, the created application provides users with a user-friendly tool to effectively analyze and compare their chosen stock picks, those they consider to have potential as hedging instruments, against traditional safe havens like gold or silver. By leveraging clear visualizations and straightforward analytics, the application empowers even nontechnically skilled users to assess the viability of their selections in the context of market volatility and geopolitical uncertainty, aiding them in making more informed investment decisions.

2 Input Data

The minute-level historical data retrieved from Polygon.io were utilized, with an individual API key securely stored in an .env file. The user can specify the desired time period for any chosen stock and select whether to compare it with gold or silver as a hedging instrument. Due to API limitations, the maximum allowable time range was set to six months.

Methods and Tools

To implement the analysis, several Python libraries were leveraged to perform key financial modeling and visualization tasks. **NumPy** and **Pandas** were used for data manipulation, including calculating logarithmic returns and scaling data to ensure numerical stability in models. Visualization of trends and volatility comparisons was achieved using **Matplotlib**, providing clear and informative graphical outputs. For statistical tests, such as the **Jarque-Bera test** to check for the normality of residuals, **SciPy.stats** were utilized. The core of the analysis relied on the **ARCH** package, which allowed implementing the **GARCH** models for the estimation of volatility and the **GJR-GARCH** models to capture asymmetric effects in financial data. Together, these packages provided a robust framework for performing analysis efficiently and accurately.

Results

The application provides users with three interactive tabs, each designed to facilitate visualization.

- **Price Data Visualization:** This tab offers a clear graphical representation of the historical prices of the selected stock and the chosen hedging instrument (gold or silver) over the specified time horizon.
- **Correlation Analysis:** In this tab, users can explore the log returns of their selected stock and the hedging instrument. The tab includes a rolling correlation chart that allows users to examine how the relationship between the two assets evolves over time.
- **Volatility Modeling:** This tab focuses on fitting a Generalized Autoregressive Conditional Heteroskedasticity model, developed by Robert F Engle [3] to the selected stock's historical data. This model provides users with a detailed view of time-varying volatility and

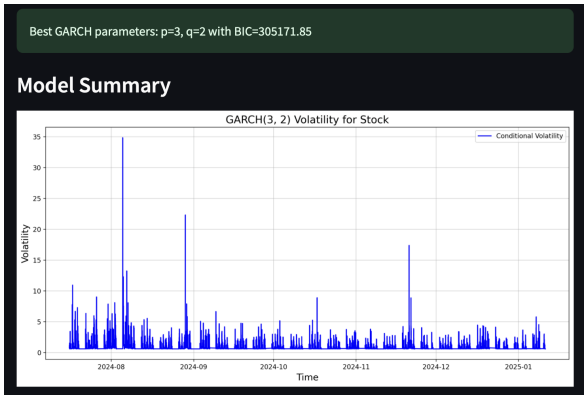

Figure 1: An example of fitted GARCH for NVDA stock

volatility clustering, helping them evaluate the stock's behavior under changing conditions, such as geopolitical risks. In the context of a GARCH(p, q) model, the parameters p and q are critical to determine the influence of the past information on the current volatility. The value of p reflects the extent to which the model relies on past shocks or sudden market changes to predict current volatility, while q indicates the degree to which past volatility levels affect the present. A model with lower values of p and q (such as GARCH(1,1)) places greater emphasis on the most recent market movements. The project also tests whether the GJR-GARCH model is not more suitable. This advanced variant of the standard GARCH model has proven particularly adept at capturing the leverage effect in financial time series. The leverage effect refers to the phenomenon in which negative asset returns (e.g. bad news) tend to have a more pronounced effect on future volatility than positive returns (e.g. good news) of the same magnitude.

Constraints and Recommendations for Improvement

Initially, the project also aimed to include an analysis incorporating the geopolitical risk index (GPR) [2]. Unfortunately, due to the lack of access to a suitable API, this feature could not be implemented. However, incorporating the GPR index remains a promising avenue for future development. By adding this index, the application could allow users to compare their chosen stock's volatility with global geopolitical risk levels, enriching the hedging analysis.

Another possible implemented feature would be the wavelet coherence analysis. Implementing this feature would however require substantial computational resources. This method, widely used for comparing hedging instruments, could provide deeper insights into the relationship between the GPR Index, the selected stock and established hedging instruments.

3 Conclusion

The author found the development of this application both enriching and enjoyable, as it provided an opportunity to explore new tools (e.g. Streamlit) and tackle a problems outside his usual academic focus. While the application effectively serves its purpose for analyzing volatility and comparing hedging instruments, it is clear that its use is not to be the broadest, and furthermore, improvements can be considered and further applied.

References

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Disclaimer

The author believes that he utilized tools such as Chat GPT in compliance with university guidelines, primarily for ensuring the codestyle, proper code comment documentation, debugging, and to assist with PyTest implementation. Further information can be found in the README file.