# Understanding Risk: Comparing High-Risk vs. Low-Risk Investments

Pooja Goel (23BCT0106)
*School of Computer Science & Engineering*
*Vellore Institute of Technology (VIT)*
Vellore, India
pooja.goel2023@vitstudent.ac.in

Dr. Sujatha V.*
*School of Advanced Sciences*
*Vellore Institute of Technology (VIT)*
Vellore, India
sujatha.v@vit.ac.in

(*Corresponding author)

***Abstract*—** Understanding the tradeoff between risk and return is crucial for effective investment decisions, especially in markets characterized by volatility and asset diversity. This study compares high-risk assets—Tesla (TSLA) and Bitcoin (BTC-USD)—with lower-risk alternatives—AGG (aggregate bond ETF) and BIL (T-Bill ETF)—to empirically examine differences in risk and performance. Using historical data from 2021 to 2025, we analyze price trends, calculate annualized returns and volatilities, and evaluate risk-adjusted performance via the Sharpe Ratio. Results highlight the substantial volatility and high return potential of TSLA and BTC-USD, in contrast with the stability of BIL and the underperformance of AGG amid rising interest rates. The analysis underscores the dynamic nature of asset risk profiles and reinforces the need for investors to align risk tolerance with market conditions and asset characteristics when constructing portfolios.

**Keywords—**Annualized Volatility, Annualized Return, Sharpe Ratio, investment Risk, Risk-Free Rate

## I. Introduction

The expansion of varied asset classes—ranging from traditional instruments like bonds and equities to emerging categories such as cryptocurrencies and niche ETFs—necessitates a clear understanding of their respective risk-return profiles for informed investment decision-making [1]. Successfully navigating this increasingly complex financial environment goes beyond recognizing that asset classes behave differently; it requires a data-driven understanding of the extent of these differences in terms of return potential and exposure to volatility. Such insights are critical for constructing portfolios that align with specific financial objectives and individual risk tolerances.

Assets like government securities or aggregate bond funds are typically chosen for their perceived safety and consistent, albeit modest, returns. In contrast, growth-oriented technology stocks and digital assets appeal to investors due to their higher potential for capital appreciation, though often accompanied by elevated levels of uncertainty and price swings [2].

While financial theory suggests a direct relationship between risk and return, applying empirical evidence to real-world asset performance adds meaningful context. Theoretical constructs become more actionable when substantiated by observed behaviour of well-known investment instruments. In this study, a comparative empirical assessment is conducted using examples that represent opposite ends of the perceived risk continuum. Tesla (TSLA), a notable high-growth stock, and Bitcoin (BTC-USD), a leading cryptocurrency, are analysed as illustrations of high-risk investments. These are evaluated against lower-risk options such as the iShares Core U.S. Aggregate Bond ETF (AGG) and the SPDR Bloomberg 1-3 Month T-Bill ETF (BIL).

The purpose of this comparative framework is to deliver a practical understanding of the divergent risk and return characteristics inherent to each asset class. By analysing metrics such as historical returns, price volatility, and risk-adjusted performance, the study aims to offer data-backed insights that can help investors calibrate expectations and develop more resilient investment strategies. Moreover, this analysis serves an educational function by showcasing how essential financial measures—such as the Sharpe Ratio—can be applied in evaluating contrasting investment alternatives. Observing how these well-known assets performed relative to one another and to low-risk benchmarks contributes to a deeper understanding of asset behaviour and helps in forming projections about potential future performance.

Consequently, the core objectives of this research are:

- To document and contrast the historical annualized returns and annualized volatility metrics for TSLA, BTC-USD, AGG, and BIL over the period January 1, 2021, to April 1, 2025.
- To calculate and compare the Sharpe ratios for these four assets to assess their performance on a risk-adjusted basis.
- To use these findings to discuss the practical implications of the risk-reward tradeoff as observed in these specific market examples.

The data used for this analysis comprises historical adjusted closing prices sourced from Yahoo Finance. Standardized financial methodologies are employed to compute the relevant metrics. The structure of the paper is as follows: Section 3 outlines the methodology, Section 5 showcases the analysis results, Section 6 explores the implications and limitations, and Section 7 wraps up the study with concluding remarks.

## II. Literature Review

This study investigates the risk and return characteristics of diverse asset classes by applying established financial theories and metrics to recent market data. The core concepts underpinning this research include the fundamental relationship between risk and reward, standard methods for

quantifying these attributes, the importance of risk-adjusted performance measures, and the documented characteristics of the specific asset classes examined.

### *A. The Risk-Reward Tradeoff*

A foundational concept in finance is the expected positive correlation between investment risk and potential return. Modern Portfolio Theory (MPT), largely attributed to Markowitz, posits that investors are generally risk-averse and require higher expected returns as compensation for bearing higher levels of uncertainty or risk [1]. Risk, within this framework, is commonly proxied by the statistical variance or standard deviation of returns. MPT suggests an "efficient frontier" representing portfolios that offer the maximum expected return for a given level of risk [1], [2]. This implies that assets perceived by the market as riskier, such as certain equities or emerging asset classes, are expected to offer higher average returns over time than less risky assets like high-quality bonds, though this is not guaranteed in any specific period [2]. Empirical studies often use scatter plots comparing realized volatility and return to visually assess this tradeoff across different assets or timeframes [3].

### *B. Measuring Return and Risk*

Quantifying return typically involves calculating the percentage change in an asset's value over specified intervals (e.g., daily, monthly). For accurate historical analysis, especially for stocks and ETFs, using Adjusted Close Prices is critical as they account for corporate actions like dividends and splits, reflecting the total return to the investor [4]. These periodic returns are often annualized to facilitate comparison across different time horizons [2].

Volatility, measured as the annualized standard deviation of periodic returns, serves as the standard proxy for total investment risk, quantifying the dispersion of returns around the average [5]. It is well-documented that different asset classes exhibit distinct volatility levels, with equities generally showing higher volatility than bonds, and certain alternative assets demonstrating significantly higher fluctuations [Citation Needed - Asset Class Comparison Study - Replace this]. However, market volatility is often time-varying, exhibiting periods of high and low fluctuation, a phenomenon sometimes referred to as volatility clustering [6]. Therefore, analysing rolling volatility—calculating standard deviation over a moving time window—is recognized as a valuable technique for capturing the dynamic nature of an asset's risk profile, revealing changes that a single, period-wide volatility figure might obscure [5]. Additionally, analysing the full distribution of returns using tools like histograms provides further insight into risk by illustrating return frequency, skewness, and the potential for extreme outcomes (tail risk) [7].

### *C. Risk-Adjusted Performance Evaluation*

Comparing investments based solely on return ignores the crucial dimension of risk. The Sharpe Ratio, developed by William F. Sharpe, is a widely accepted metric for evaluating risk-adjusted returns [8]. It measures the excess return (asset return minus the risk-free rate) earned per unit of total risk (standard deviation). A higher Sharpe Ratio indicates superior performance relative to the risk incurred [8], [2]. The risk-free rate represents the theoretical return of an investment with zero risk, commonly proxied by the yield on short-term government securities like U.S. Treasury Bills [2].

### *D. Characteristics of Analysed Asset Classes*

The assets selected for this study represent categories with distinct documented characteristics:

High-Growth Stocks (e.g., TSLA): Often exhibit high volatility due to sensitivity to growth expectations, market sentiment, competition, and sector-specific news [9]. Their valuation can be challenging and subject to large revisions based on future projections.

Cryptocurrencies (e.g., BTC-USD): Characterized in literature by extreme price volatility driven by factors including adoption trends, regulatory developments, technological milestones, network security, and significant speculative interest, often displaying cyclical patterns distinct from traditional assets [10], [11].

Aggregate Bond ETFs (e.g., AGG): Representing the broad investment-grade bond market, these are typically less volatile than equities but are sensitive to changes in interest rates (prices generally fall when rates rise) and credit conditions [12]. Duration serves as a fundamental metric for assessing an asset's sensitivity to changes in interest rates.

Short-Term Treasury Bill ETFs (e.g., BIL): Considered ultra-low risk investments whose value primarily reflects the accrual of interest on underlying short-term government debt, often used as cash equivalents or proxies for the risk-free rate due to their minimal credit and duration risk [2], [12].

### *E. Contextualizing the Current Study*

While these theoretical concepts and general asset characteristics are well-established, ongoing empirical validation using contemporary data and specific asset examples remains valuable. This study contributes by applying these standard metrics and analytical techniques to compare TSLA, BTC-USD, AGG, and BIL during the specific, economically distinct period of 2021-2025, which included significant inflation and rapid interest rate adjustments. Through the analysis of realized returns, overall and rolling volatility, and risk-adjusted performance, this paper presents a timely and practical overview of how various assets performed and interacted within the risk-return landscape during the specified period, offering valuable insights for present-day investors.

## III. METHODOLOGY

This study uses a quantitative approach to compare the risk and yield characteristics of four different assets representing different segments of the investment spectrum: Tesla Inc. (TSLA), Bitcoin (BTC-USD), the iShares Core U.S. Aggregate Bond ETF (AGG), and the SPDR Bloomberg 1-3 Month T-Bill ETF (BIL).

### *A. Data Acquisition and Scope*

The analysis is based on historical pricing data taken directly from *Yahoo Finance.* A daily adjusted final price was used for all four assets to ensure that performance calculations reflect the overall revenues of the shareholders as a whole. This price series consists of naturally dividend payments and corporate campaigns such as stocks, providing a reliable basis for historical comparisons. The specific time frames selected for this survey will be extended from January 1, 2021 to April 1, 2025. This is a period selected for the latest market dynamics, including significant volatility in growth capacity and changes in interest rate policies.

*B. Return Metrics*

A simple monthly return was calculated for each asset from the strict prices of daily adaptation. This served as the main input for subsequent analyses. To facilitate comparisons over several years and summarise average performance, annual revenue was calculated by multiplying the arithmetic mean of the monthly returns by twelve.

*C. Risk Metrics and Distribution Analysis*

Investment risk was primarily quantified using Annualized Volatility, calculated as the annualized standard deviation of the monthly returns. This metric provides a standardized measure of the total price distribution for each asset over the entire period. Recognizing that risk profiles can change dynamically, 12-Month Rolling Annualized Volatility was also computed using a moving 12-month window on the monthly return series. This approach allows for visualizing the evolution of each asset's risk level over time. Further insights into risk characteristics were derived from analysing the Distribution of Monthly Returns. Visualizations, including histograms with Kernel Density Estimation (KDE) curves and box plots, were used to examine the frequency, spread, central tendency, and potential for extreme monthly outcomes.

The following metrics were calculated based on the derived monthly returns:

1. *Monthly Return:* Simple monthly returns were calculated from the daily adjusted closing prices using (1):

$$\text{Monthly return for month m} = \left(\frac{price\ at\ end\ of\ month\ m}{\text{price at end of previous month m} - 1}\right) - 1 \quad (1)$$

where price at end of month m is the adjusted close price at the end of month m, and price at end of previous month m-1 is the adjusted close price at the end of the preceding month.

2. *Annualized Return (Simple):* Calculated by multiplying the arithmetic mean of the calculated monthly returns by twelve, as shown in (2):

$$Annualized\ return = (mean\ of\ monthly\ return * 12) \quad (2)$$

*(Note: This simple annualization method is used for direct comparison based on average monthly performance within the period).*

3. *Annualized Volatility:* Calculated as the sample standard deviation of the calculated monthly returns multiplied by the square root of twelve, representing the annualized standard deviation of returns, shown in (3):

$$Annualized\ Volatility = standard\ deviation\ of\ month\ ly\ returns * square\ root(12) \quad (3)$$

4. *12-Month Rolling Annualized Volatility*: Calculated using a 12-month rolling window applied to the monthly return series. For each window, the Annualized Volatility was computed using the method described in (3).

5. *Sharpe Ratio:* Calculated to measure risk-adjusted return using (4):

$$Sharpe\ Ratio = \frac{(Annualized\ Return\ of\ the\ asset\ -\ Risk - Free\ Rate)}{Annualized\ Volatility\ of\ the\ asset} \quad (4)$$

where Annualized Return of the asset is the value calculated using (2), Risk-Free Rate is the rate of return of a theoretical risk-free investment, and Annualized Volatility of the asset is the value calculated using (3). For this analysis, the Risk-Free Rate was proxied by the calculated average Annualized Return of the BIL ETF over the entire analysis period.

*D. Evaluating Risk-Adjusted Returns: The Sharpe Ratio)*

To evaluate how effectively each asset compensated for the risk it carried, the Sharpe Ratio was computed. This measure quantifies risk-adjusted performance by determining the amount of excess return—defined as the difference between the asset's annualized return and a risk-free benchmark—generated per unit of volatility. In this study, the BIL ETF was used as a real-world proxy for the risk-free rate, offering a stable, ultra-low-risk reference point. This approach ensures that comparisons are grounded in practical investment conditions, and helps highlight which assets offered better returns relative to their risk exposure.

*E. Analytical and Visualization Techniques for Data Interpretation*

All data processing, metric calculations, and analytical graphics generation were performed using the *Python programming language*. Important libraries used included *Pandas, Matplotlib and Seaborn* visualizations for data manipulation and analysis. The graphical representations employed include log-scale price trends, normalized performance comparisons, return distribution charts, a volatility comparison bar chart, a risk-reward scatter plot, and rolling volatility line graphs, each chosen to highlight specific comparative aspects of the assets' performance and risk profiles.

While the primary focus of this paper is the comparative analysis presented in Section IV, detailed individual analyses for each asset, including specific interpretations of price trends, return distributions, and rolling volatility, are provided in Appendices A through D.

## IV. Research Elaborations

To conduct a comprehensive comparison of the selected high-risk (TSLA, BTC-USD) and low-risk (AGG, BIL) assets, a multi-faceted analytical approach was adopted. This section explains how the reasons for inclusion in evaluations of performance, risk, and inherent compromises during the period from January 2021 to April 2025 are most important, as well as the role and significance of visualization.

*A. Establishing Baseline Performance and Risk*

- *Core Metrics (Annualized Return, Volatility, Sharpe Ratio):* The initial calculation of overall Annualized Return and Annualized Volatility serves as the fundamental quantitative baseline. Annualized Return standardizes the performance measurement across the multi-year timeframe, indicating the average yearly gain or loss. Annualized Volatility, calculated as the annualized standard deviation of monthly returns, provides quantitative standard proxy for overall risk, representing the typical magnitude of price fluctuations. However, viewing return in isolation is insufficient; the Sharpe Ratio is therefore calculated as a crucial metric for risk-adjusted performance. Contextualize returns measured by measuring excess returns per unit of volatile risk compared to a risk-free scale (from BIL). Together, these three metrics provide a brief summary of individual assets in terms of compensation, risk and efficiency of the overall asset throughout the period.

*B. Visualizing Price Dynamics and Comparative Growth*

- *Logarithmic Price Trend Visualization:* Raw price comparisons can be misleading due to drastic differences in absolute values across asset classes. For instance, comparing Bitcoin to short-term T-Bills directly on a linear scale can obscure meaningful trends. Using a logarithmic scale resolves this issue by ensuring equal distances represent equal percentage changes rather than raw price differences. This method enhances clarity in observing growth rates and volatility trends, offering a fair comparative view of assets like TSLA, BTC-USD, AGG, and BIL.

- *Normalized Performance Analysis:* To directly compare the investment journey from a common starting point, *normalized price performance* was plotted. By indexing the starting value of all assets to 100, this visualization removes the effect of initial price differences and clearly illustrates the relative growth or decline of an initial investment in each asset over the analysis period. It directly addresses the question of which asset provided superior cumulative performance from the beginning of the period.

*C. Deepening the Understanding of Risk*

- *Return Distribution Analysis (Histograms & Box Plots):* While volatility gives a single number summarizing risk, deeper insight comes from examining the monthly return distribution. Histograms show how often returns fall into specific ranges, uncovering the shape of the distribution—whether it's skewed, peaked, or contains fat tails. Box plots add statistical detail, summarizing medians, interquartile ranges, and identifying outliers. Together, they provide a visual and statistical narrative about the consistency of returns, extreme scenarios, and how unpredictable an asset may be beyond just its volatility.

- *Rolling Volatility (Dynamic Risk Tracking):* Financial market risk is rarely constant. External events, policy changes, and shifting market sentiment can alter an asset's volatility over time. As a result, computing and visualizing the 12-month rolling annualized volatility was considered essential. This analysis reveals how the measured risk level of each asset evolved throughout the 2021-2025 period, identifying periods of heightened or diminished risk. It moves beyond the static overall volatility figure to provide a dynamic view, essential for understanding if an asset's risk profile remained stable or changed significantly in response to market conditions (e.g., AGG's response to interest rate hikes).

*D. Synthesizing Risk and Reward*

- *Risk-Reward Scatter Plot:* To effectively convey the study's key insights, a scatter plot mapping Annualized Return against Annualized Volatility serves as a compelling visual summary. This Risk-Reward Tradeoff chart clearly illustrates where each asset falls in terms of both risk and reward during the analysis period. It enables easy identification of patterns, such as clusters of high-risk/high-return or low-risk/low-return investments, reinforcing the core concept of the tradeoff between potential gain and exposure to risk.

By integrating these quantitative indicators with meaningful visual representations, the study goes beyond basic comparisons. It delivers a well-rounded and detailed view of how the selected assets performed from a risk-return standpoint across the chosen timeframe. Each analysis component adds depth, collectively offering a holistic perspective on the empirical relationship between risk and return.

## V. Results and Findings

This section presents the results obtained from the comparative analysis of Tesla (TSLA), Bitcoin (BTC-USD), iShares Core U.S. Aggregate Bond ETF (AGG), and SPDR Bloomberg 1-3 Month T-Bill ETF (BIL) for the period January 1, 2021, to April 1, 2025.

*A. Overall Performance and Risk Metrics*

Calculated performance metrics summarizing the overall outcomes for the entire analysis period are presented in Table I.

**Calculated Performance Metrices:**

| | ***Annualized Return*** | ***Annualized Volatility*** | ***Sharpe Ratio*** |
|---|---|---|---|
| **TSLA** | 16.90% | 61.66% | 0.23 |
| **BTC-USD** | 41.33% | 63.82% | 0.60 |
| **AGG** | -1.50% | 6.99% | -0.62 |
| **BIL** | 2.83% | 1.05% | 0.00 |

Table I. *Calculated Performance Metrics (Annualized Return, Annualized Volatility, Sharpe Ratio) for TSLA, BTC-USD, AGG, BIL (Jan 2021 - Apr 2025).*

Table I indicates significant divergence: BTC-USD and TSLA yielded high positive Annualized Returns (41.33% and 16.90%, respectively), while AGG produced a negative return (-1.58%) and BIL a low positive return (2.83%).

Annualized Volatility metrics confirm the high-risk nature of BTC-USD (63.82%) and TSLA (61.66%) compared to AGG (6.99%) and BIL (1.05%). Correspondingly, Sharpe Ratios were positive for BTC-USD (0.60) and TSLA (0.23), negative for AGG (-0.62), and zero for the benchmark BIL (0.00).

### B. *Price Dynamics and Relative Growth*

Historical price trends, plotted on a logarithmic scale for comparative analysis of relative changes, are shown in Fig. 1.

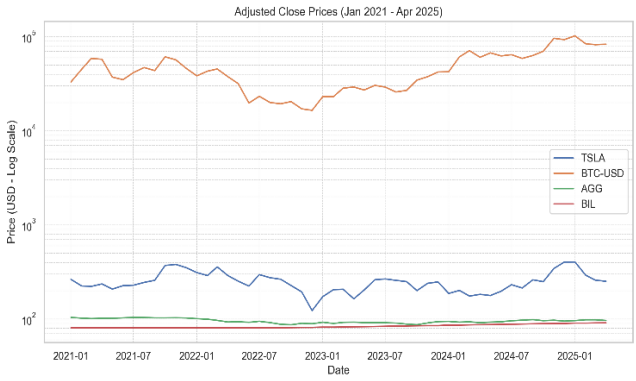


Fig. 1. *Adjusted Close Prices (Log Scale) for TSLA, BTC-USD, AGG, and BIL (Jan 2021 - Apr 2025).*

Fig. 1 highlights the extreme price fluctuations characteristic of BTC-USD and the significant swings of TSLA. It also displays AGG's decline through 2022 (the specific timing relative to Fed actions is elaborated in Appendix C.1) and subsequent partial recovery, contrasting with BIL's initial stability followed by steady accrual.

Normalized price performance, illustrating relative growth from a common starting point (Index=100), is presented in Fig. 2.

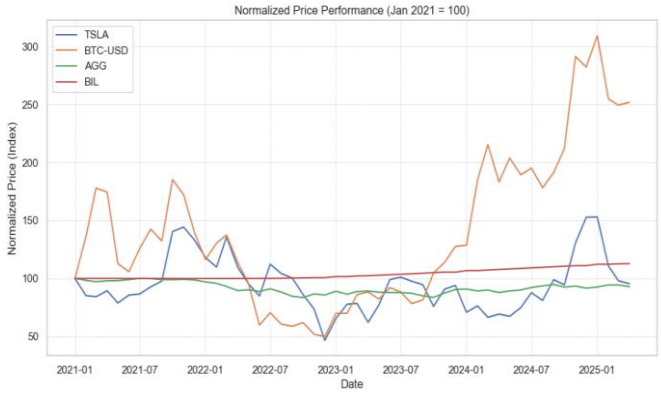


Fig. 2. *Normalized Price Performance (Index 100 = Jan 2021) for TSLA, BTC-USD, AGG, and BIL.*

Fig. 2 demonstrates BTC-USD's superior cumulative growth over the period, significantly outpacing TSLA, which ended moderately positive. AGG finished below its starting index value, while BIL showed consistent slow growth.

### C. *Monthly Return Characteristics*

The distribution of monthly returns, revealing the frequency and spread of monthly performance outcomes, is visualized in Figs. 3 and 4.


Fig. 3. *Histogram and KDE Plot of Monthly Returns for TSLA, BTC-USD, AGG, and BIL.*

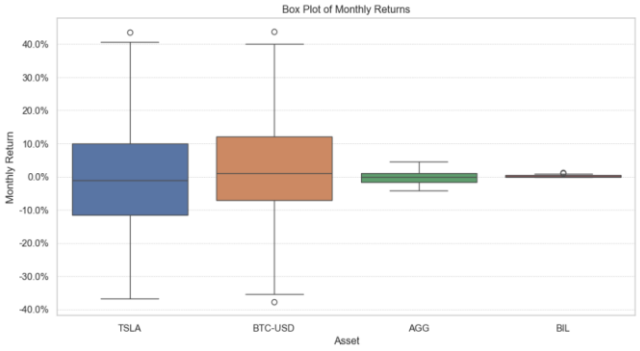


Fig. 4. *Box Plot of Monthly Returns for TSLA, BTC-USD, AGG, and BIL.*

Figs. 3 and 4 show wide distributions (-40% to +44% range) and large interquartile ranges for TSLA and BTC-USD potential for extreme results (see Appendix A.2 and Appendix B.2 for detailed statistics)., indicative of high month-to-month volatility. Conversely, AGG and BIL exhibit narrow distributions tightly clustered around zero, signifying low monthly volatility.

### D. *Dynamic Volatility Analysis*

The evolution of risk over time, captured by 12-month rolling annualized volatility, is plotted in Fig. 6. (The overall average volatility comparison is shown in Fig. 5).

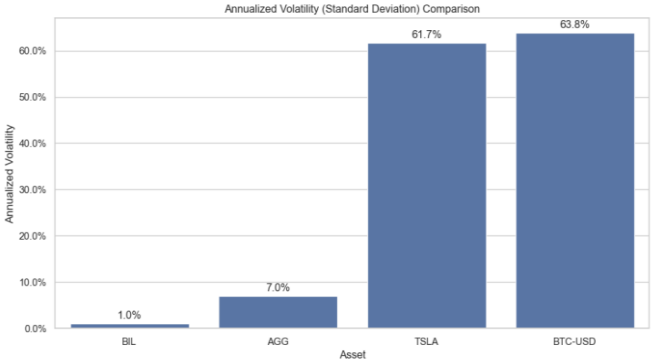


Fig. 5. *Comparison of Annualized Volatility (Standard Deviation) for TSLA, BTC-USD, AGG, and BIL.*

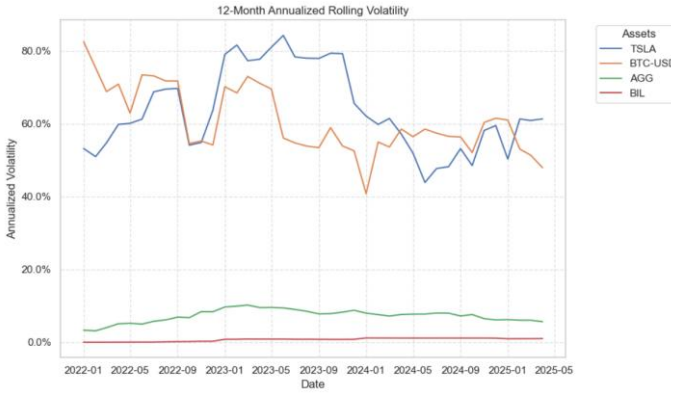


Fig. 6. *12-Month Rolling Annualized Volatility for TSLA, BTC-USD, AGG, and BIL.*

Fig. 6 demonstrates the dynamic nature of volatility. While TSLA and BTC-USD consistently maintained high rolling volatility (>40-50%), these levels fluctuated considerably, with distinct peaks and troughs observed. AGG's rolling volatility increased significantly during 2022, peaking above 10% in early 2023 demonstrating sensitivity to the rate environment (details in Appendix C.3, Fig. C3)., before moderating. BIL's rolling volatility remained consistently near zero. Fig. 5 visually reinforces the overall average volatility differences summarized in Table I.

### *E. Synthesized Risk-Reward Profile*

The relationship between overall risk (Annualized Volatility) and reward (Annualized Return) for each asset over the entire period is visualized in Fig. 7.

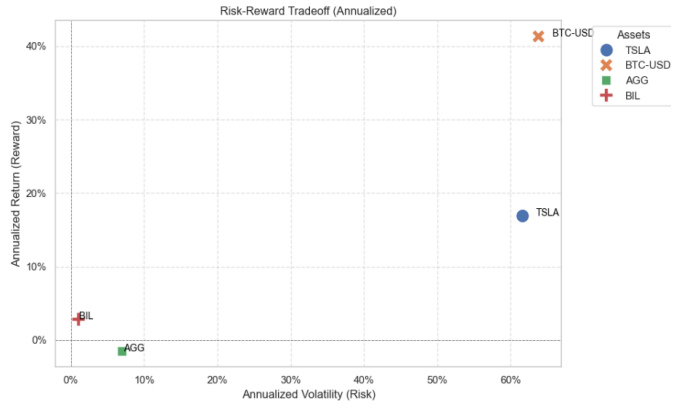


*Fig. 7: Risk-Reward Tradeoff Plot (Annualized Volatility vs. Annualized Return) for TSLA, BTC-USD, AGG, and BIL.*

Fig. 7 positions each asset on the risk-reward plane . TSLA and BTC-USD occupy the high-risk, high-return quadrant (top-right). BIL is located in the low-risk, low-return quadrant (bottom-left). AGG is positioned in the low-risk region but yielded a negative return, placing it below the zero-return axis. This plot provides a clear visual summary of the risk-return outcomes observed during the analysis period.

## VI. Discussion

The results presented in Section IV offer a data-driven comparison of four distinct asset types during a dynamic market period from January 2021 to April 2025. This section interprets the outcomes, situates them within foundational financial theory, and outlines the study's limitations.

### *A. Synthesis of Findings and Risk-Reward Implications*

The analysis highlights the broad spectrum of risk and return characteristics across various asset classes. While it generally supports the fundamental financial principle that higher risk tends to correlate with higher potential reward, the findings also underscore important exceptions driven by prevailing macroeconomic conditions.

As reflected in Table I and the risk-return scatter plot (Figure 7), TSLA and BTC-USD clearly fall into the high-risk, high-return quadrant, consistent with expectations for a volatile technology stock and a leading cryptocurrency. Both assets demonstrated substantial annualized volatility and positive returns throughout the period. In contrast, BIL—representing a short-term Treasury Bill ETF—served its expected role as a low-risk, low-return asset, anchoring the lower left of the risk-return graph with minimal fluctuations and stable returns.

However, AGG deviated from this general pattern. Despite only moderate volatility relative to TSLA and BTC-USD, AGG posted a negative annualized return and an unfavourable Sharpe ratio, as seen in Table I and Figure 7. This exception emphasizes that elevated risk levels do not always guarantee proportional rewards, especially when adverse macroeconomic developments disproportionately impact an asset class.

### *B. Understanding Individual Asset Behavior*

The negative performance of AGG (annual return: -1.58%, Sharpe ratio: -0.62) can be attributed to a shift in monetary policy, particularly the interest rate increases initiated by the Federal Reserve beginning in 2022. As rates rose to curb inflation, the value of previously issued bonds with lower yields declined—an outcome reflected in AGG's downward trend (Figure 1). This case exemplifies interest rate sensitivity, a key risk even in broadly diversified bond portfolios.

When comparing TSLA and BTC-USD, both displayed elevated volatility (Table I, Figure 5), but BTC-USD notably outperformed with a 41.33% annualized return and a Sharpe ratio of 0.60, compared to TSLA's 16.90% return and 0.23 Sharpe ratio. This suggests that during the timeframe examined, Bitcoin offered greater return per unit of risk. The price trends (Figures 1 and 2) further illustrate the contrast: BTC-USD experienced more pronounced boom-bust cycles yet delivered higher cumulative returns, while TSLA showed sharp movements but more modest overall appreciation. These observations indicate the diversity of behaviour even within high-risk asset categories.

BIL performed in line with expectations for a T-Bill ETF, generating modest positive returns that closely tracked rising short-term interest rates post-2022 (Figure 1). Its near-zero Sharpe ratio reinforced its function as a practical proxy for the risk-free rate in this analysis.

### *C. Evolving Nature of Risk Over Time*

A key finding illuminated by the rolling volatility analysis (Fig. 6) is that risk is not static. While TSLA and BTC-USD were consistently high-risk, their measured volatility levels fluctuated considerably over time, indicating changing market perceptions and conditions. More strikingly, AGG's rolling volatility, while low on average, more than doubled from its baseline during the peak period of interest rate hikes (Appendix C.3), exceeding 10%. This demonstrates that even assets typically considered "lower-risk" can experience

significant shifts in their risk profile based on the macroeconomic environment. Relying solely on long-term average volatility metrics can therefore be misleading; understanding the potential for dynamic changes in risk is crucial. BIL's consistently minimal rolling volatility further cemented its role as the stable anchor.

### *D. Practical Lessons for Investors*

The findings carry several key takeaways for investors. Firstly, the elevated volatility and broad return distribution of assets like TSLA and BTC-USD highlight the need for strong risk tolerance when investing in such instruments. Their potential for high returns is offset by the significant risk of short-term losses. Secondly, AGG's negative return during the study period demonstrates that diversification and the "low-risk" label do not eliminate vulnerability to losses, particularly when macroeconomic forces such as monetary tightening come into play. Thirdly, the comparative Sharpe ratios emphasize the importance of evaluating investments not just on return but also on the efficiency of return relative to risk. Lastly, the consistent performance of BIL underlines the value of ultra-low-risk assets in preserving capital and providing a baseline return, particularly during periods of heightened uncertainty or shifting interest rate regimes.

### *E. Limitations of the Study*

This study, while informative, is constrained by its limited time frame (January 2021 to April 2025) and the selection of only four representative assets. The findings may not fully capture long-term trends or broader asset class behaviors. Additionally, metrics like the Sharpe ratio rely on assumptions that may not always hold, especially for highly volatile assets like cryptocurrencies. Despite these limitations, the analysis offers valuable insights into the risk-return dynamics under recent market conditions.

## VII. Conclusion

This study undertook a quantitative evaluation of the risk-return profiles of four distinct assets—TSLA, BTC-USD, AGG, and BIL—spanning high-growth equity, cryptocurrency, aggregate bonds, and Treasury bills. The analysis covered the period from January 2021 to April 2025 and aimed to empirically illustrate the tradeoff between risk and reward across different asset classes during a volatile market phase.

The findings revealed clear disparities in both performance and risk characteristics. As anticipated, the higher-risk assets, TSLA and BTC-USD, exhibited significantly elevated annualized volatility when compared to their lower-risk counterparts, AGG and BIL. While both high-risk assets achieved positive annualized returns, BTC-USD notably delivered exceptionally high returns alongside the most favorable Sharpe ratio, suggesting it offered better compensation relative to the substantial risk assumed during this period. The SPDR Bloomberg 1-3 Month T-Bill ETF (BIL) functioned effectively as the risk-free benchmark, offering consistent, low positive returns with minimal volatility.

A particularly notable finding was the weaker performance of the iShares Core U.S. Aggregate Bond ETF (AGG), which recorded negative returns and a corresponding negative Sharpe ratio despite its moderate risk level. This outcome is largely attributed to the adverse effects of rising interest rates during the analysis period. Additionally, the rolling volatility analysis highlighted that risk was not constant over time—particularly for AGG—demonstrating the dynamic nature of market risk in response to macroeconomic developments.

In summary, this research confirms the general principle that greater potential returns are often accompanied by higher risk. However, it also emphasizes the importance of context—especially the impact of broader economic trends like interest rate fluctuations—on asset performance. The study reinforces the need for investors to look beyond headline returns by incorporating risk-adjusted performance metrics, such as the Sharpe ratio, and considering the evolving nature of asset risk over time. It also serves as a reminder that even traditionally safer assets may face losses under certain market conditions, making it crucial to match investment strategies with personal risk profiles and an awareness of the prevailing economic environment. Future research could enhance these findings by extending the analysis to longer timeframes or incorporating a broader set of assets across all risk categories

## Appendices

The following appendices provide detailed individual analyses for each of the four assets included in the comparative study, presenting specific price trends, return distributions, rolling volatility patterns, and interpretations for the period January 1, 2021, to April 1, 2025.

### Appendix A: Tesla (TSLA) Individual Analysis

#### *A.1. TSLA Price Trend Analysis*

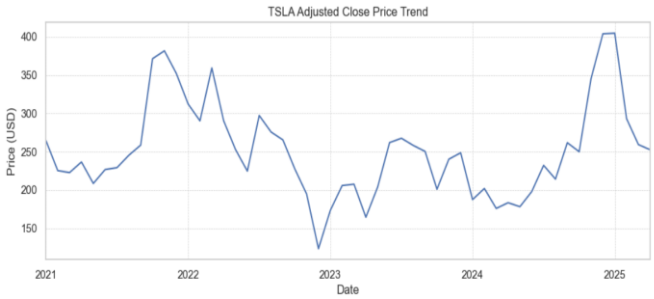


Fig. A1. *TSLA Adjusted Close Prices (Jan 2021 - Apr 2025).*

Interpretation Summary: The price trend for TSLA clearly demonstrates characteristics of a volatile growth stock. Key observations include significant price fluctuations with sharp peaks and deep troughs rather than a smooth progression. The stock reached notable highs approaching $400 late 2021/early 2022 and again late 2024/early 2025, while also experiencing major drawdowns, hitting lows below $150 in late 2022/early 2023. Despite large intermediate movements, the price at the end of the observed period (around $250) is relatively close to the starting price (around $265), indicating significant volatility without a strong overall upward or downward trend across this specific timeframe. This visually confirms TSLA's high-risk classification.

*A.2. TSLA Return Analysis*

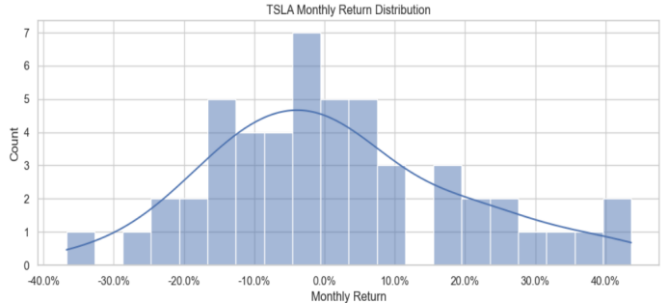


Fig. A2. *Distribution of Monthly Returns for TSLA.*

Interpretation Summary: The distribution of TSLA's monthly returns confirms significant volatility, as shown in the histogram (Fig. A2). Returns range from substantial losses (-36.73% min) to substantial gains (+43.65% max), based on the descriptive statistics. The histogram shows a wide spread, roughly centred around zero but slightly skewed by large positive/negative outcomes. The average monthly return (mean) was positive at 1.41%, but the median monthly return (-1.12%) was slightly negative, suggesting large positive months drove the average while slightly more than half the months experienced negative returns. The monthly standard deviation (17.80%) quantitatively confirms the large dispersion and high-risk nature.

*A.3. TSLA Rolling Volatility Analysis*

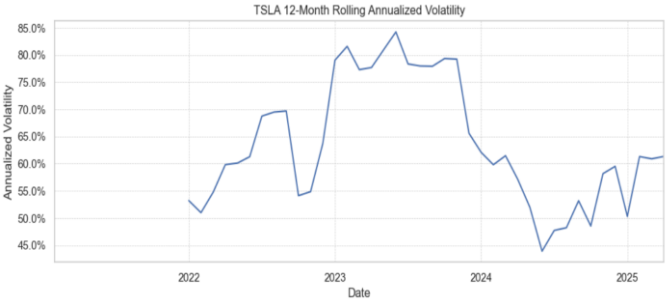


Fig. A3. *TSLA 12-Month Rolling Annualized Volatility*.

Interpretation Summary: TSLA's estimated annualized volatility remained significantly elevated throughout the period, generally fluctuating between approximately 45% and 85%, confirming persistent high levels of risk. Risk was not static; there was a clear upward trend in volatility through 2022, peaking near 85% in the first half of 2023. Following this peak, volatility generally declined, reaching a relative low below 45% in early 2024, suggesting a comparatively calmer (though still high-risk) period. Towards the end of the observed period (late 2024 into 2025), volatility appears to be trending upwards again, moving back above the 60% mark.

*A.4. Conclusion for TSLA*

Summary: TSLA exhibited patterns characteristic of a highly volatile growth stock during the 2021-2025 period. Its price experienced significant swings, including peaks near $400 and troughs below $150, without establishing a clear overall trend from start to finish. This visual volatility was quantified by a wide monthly return distribution (ranging from -37% to +44%) and a high monthly standard deviation (around 18%). Furthermore, its 12-month rolling volatility remained elevated, mostly fluctuating between 45% and 85%, confirming its classification as a high-risk asset. Despite this risk and a negative median monthly return, TSLA generated a positive average monthly return (+1.4%), indicating it was beneficial in terms of average capital appreciation during this specific timeframe, albeit accompanied by substantial risk.

**Appendix B: Bitcoin (BTC-USD) Individual Analysis**

*B.1. BTC-USD Price Trend Analysis*

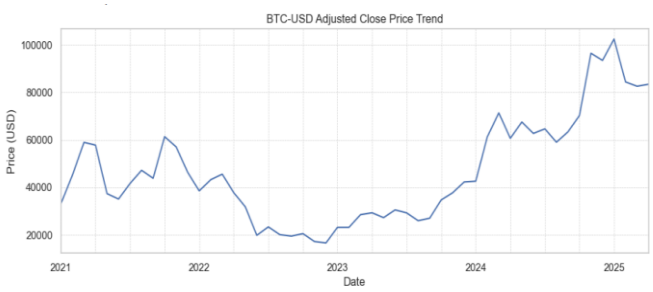


Fig. B1. *BTC-USD Adjusted Close Prices (Jan 2021 - Apr 2025).*

Interpretation Summary: Bitcoin's price trend vividly illustrates extreme volatility. The price fluctuated dramatically, starting around $30,000-40,000, peaking above $60,000 in 2021, crashing below $20,000 during 2022, and then embarking on a strong recovery rally through 2023 and 2024, ultimately exceeding $100,000 in early 2025 before pulling back. The chart shows distinct "boom and bust" cycles: a significant rally, sharp corrections ("crypto winter"), and a powerful subsequent bull run. The visual magnitude of BTC-USD's price swings appears even more pronounced than TSLA's over the same period, confirming its exceptionally high-risk nature.

*B.2. BTC-USD Return Analysis*

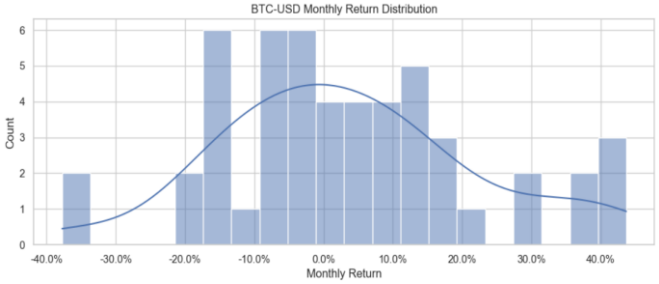


Fig. B2. *Distribution of Monthly Returns for BTC-USD.*

Interpretation Summary: The histogram (Fig. B2) reveals a very wide distribution of monthly returns, spanning roughly -40% to +40%, indicating extremely high volatility. The distribution shows significant weight in both positive and negative tails. The average monthly return (mean) was strongly positive at 3.44%, significantly boosted by months with very large positive returns, while the median return was smaller but also positive (1.04%). The monthly standard deviation (18.42%) is exceptionally high, comparable to TSLA's, confirming extreme volatility. The >80 percentage point range between min/max monthly returns underscores the immense potential price swings.

*B.3. BTC-USD Rolling Volatility Analysis*

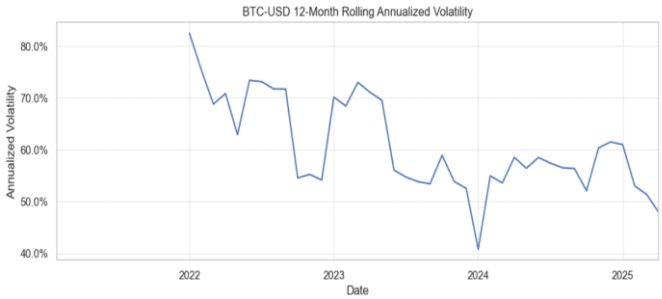


Fig. B3. *BTC-USD 12-Month Rolling Annualized Volatility.*

Interpretation Summary: Bitcoin's rolling volatility remained at very high levels throughout the entire period, generally oscillating between approximately 40% and over 80%, confirming its persistent nature as an extremely high-risk asset. The risk level was far from constant; volatility was highest at the beginning of the displayed period (early 2022), exceeding 80%, then trended downwards with considerable fluctuations, reaching lows around 55% in mid-2022 and mid-2023. A particularly sharp decrease occurred towards the end of 2023, bottoming out near 40% in early 2024, before climbing again through 2024. Compared to TSLA, Bitcoin's rolling volatility appears quite erratic with frequent sharp changes in direction.

*B.4. Conclusion for BTC-USD*

Summary: BTC-USD displayed distinct cyclical patterns between 2021 and 2025, characterized by dramatic price surges ("booms") reaching peaks over $60,000 and later exceeding $100,000, punctuated by sharp declines ("busts") with lows below $20,000. Its risk profile is classified as extremely high, confirmed by a wide monthly return distribution (spanning roughly -40% to +40%), a high standard deviation (around 18%), and consistently elevated rolling volatility (mostly 40%-80%). Despite this immense risk and potential for severe drawdowns, BTC-USD generated a strong positive average monthly return (~3.4%) over this specific timeframe. Therefore, while proving beneficial in terms of average returns during this period, its extreme volatility underscores the significant speculative risk involved.

**Appendix C:Aggregate Bond ETF (AGG) Individual Analysis**

*C.1. AGG Price Trend Analysis*

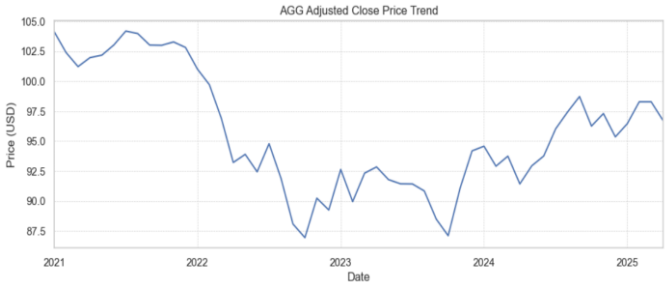


Fig. C1. *AGG Adjusted Close Prices (Jan 2021 - Apr 2025).*

Interpretation Summary: AGG's price trend reflects typical broad bond market behaviour, particularly during a period of shifting interest rates. Compared to high-risk assets, price movement is considerably smoother, although it exhibits more fluctuation than the ultra-low-risk BIL ETF. The most prominent feature is the significant decline starting in late 2021 and extending through most of 2022, reaching a low point below $90. This period directly corresponds to the Federal Reserve's aggressive interest rate hikes. As interest rates rise, the value of existing bonds with lower yields typically falls. From the low point in late 2022/early 2023, the ETF shows a general recovery trend through 2024 and into early 2025, ending around $97.5. Despite the recovery, the ETF ended significantly below its starting price (above $102.5).

*C.2. AGG Return Analysis*


Fig. C2. *Distribution of Monthly Returns for AGG.*

Interpretation Summary: The histogram (Fig. C2) displays a relatively narrow return distribution compared to high-risk assets, indicating lower volatility. Returns are largely clustered around the 0% mark, spanning roughly from -4% to +4%. The average monthly return (mean) was slightly negative at -0.13%, consistent with the overall price decline observed. The median return was also very close to zero at -0.02%. The monthly standard deviation (2.02%) is significantly lower than for TSLA/BTC-USD but considerably higher than for BIL, confirming AGG's position as a low-to-moderate risk asset. The range (-4.15% min to 4.57% max) shows noticeable monthly movements, though much tighter than high-risk assets.

*C.3. AGG Rolling Volatility Analysis*

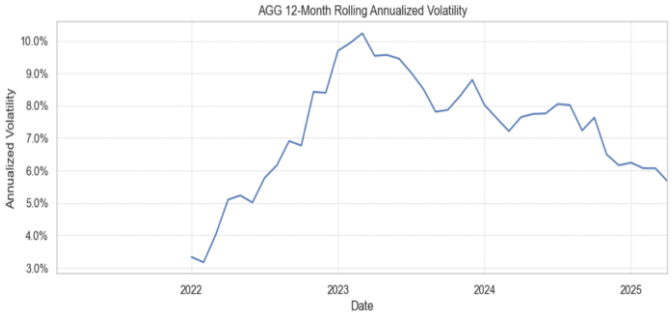


Fig. C3. *AGG 12-Month Rolling Annualized Volatility.*

Interpretation Summary: While AGG's volatility was consistently far below that of TSLA and BTC-USD, it was not static and clearly exceeded the near-zero volatility of BIL. There is a distinct and significant increase in rolling volatility throughout 2022, peaking above 10% in early 2023. This period aligns directly with the Federal Reserve's rapid interest rate increases, which introduced significant uncertainty and price fluctuations into the usually more stable bond market. Following the peak in early 2023, AGG's rolling volatility generally trended downwards throughout 2023 and 2024, stabilizing in the 6%-8% range towards the end of the period. This dynamic view shows even diversified bond funds like

AGG can experience considerable changes in their risk profile.

*C.4. Conclusion for AGG*

Summary: AGG exhibited clear patterns between 2021 and 2025, notably a significant price decline during the period of rising interest rates, followed by a partial recovery. Its risk profile was identified as low-to-moderate, with rolling volatility climbing above 10% amidst rate uncertainty before later moderating. However, as AGG generated a negative average return over this specific timeframe, it resulted in a capital loss for holders. Therefore, based purely on performance during this period, it proved not to be beneficial from a return perspective, highlighting the significant impact of interest rate risk on bond fund investments.

**Appendix D: T-Bill ETF (BIL) Individual Analysis**

*D.1. BIL Price Trend Analysis*

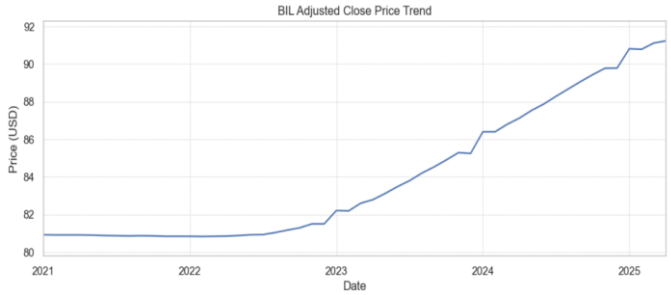


Fig. D1. *BIL Adjusted Close Prices (Jan 2021 - Apr 2025).*

Interpretation Summary: BIL's price trend clearly reflects its function as an ultra-low-risk, cash-equivalent investment. For the initial part of the period (2021 through 2022), the price is remarkably stable, hovering just below $81 dollars with minimal fluctuation. Beginning in late 2022/early 2023, the price exhibits a smooth and steady upward trend, climbing consistently to over $91 dollars by early 2025. This upward movement primarily reflects the accrual of interest from the underlying short-term Treasury bills. The noticeable steepening of the upward trend from 2023 onwards likely corresponds to the period of rising short-term interest rates set by the Federal Reserve. The chart lacks the sharp peaks and troughs seen in TSLA or BTC-USD, demonstrating its focus on capital preservation rather than capital appreciation through price swings.

*D.2. BIL Return Analysis*

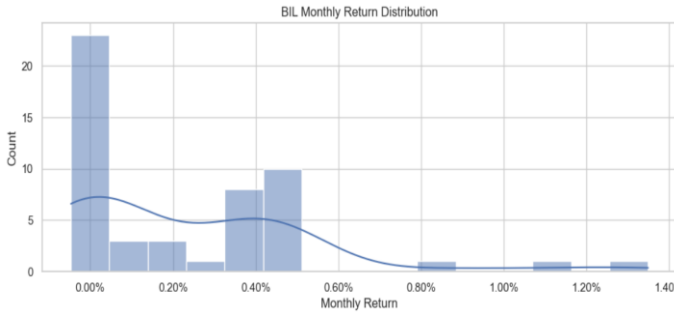


Fig. D2. *Distribution of Monthly Returns for BIL.*

Interpretation Summary: The histogram (Fig. D2) shows an extremely narrow distribution, heavily concentrated at the low end of the positive return spectrum. The vast majority of returns fall between 0.00% and approximately 0.50%. This visually confirms the asset's exceptionally low volatility. The average monthly return (mean) was 0.2361% and the median return was 0.1359%. Both are small positive values, reflecting the modest yields from short-term T-bills during the period. The monthly standard deviation (std) is incredibly low at 0.3026%. This is orders of magnitude smaller than the volatility observed for AGG, TSLA, or BTC-USD, quantifying its minimal risk profile. The very narrow range between the min (-0.0469%) and max (1.3490%) monthly returns further emphasizes the low risk.

*D.3. BIL Rolling Volatility Analysis*

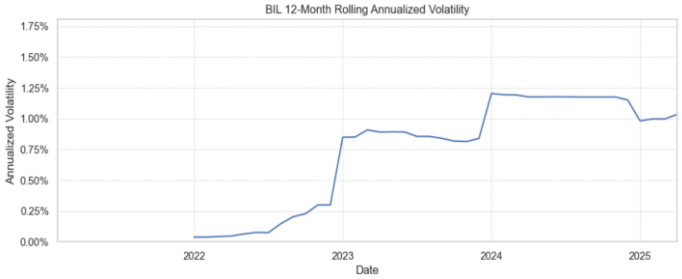


Fig. D3. *BIL 12-Month Rolling Annualized Volatility.*

Interpretation Summary: BIL's rolling volatility remained exceptionally low and stable throughout the entire analysis period. It consistently hovered near or just above 0%, with a maximum peak only reaching around 1.25%. This plot visually confirms BIL's minimal risk profile and its stability even during periods of broader market turbulence or changing interest rates (though its return reflects those rate changes).

*D.4. Conclusion for BIL*

Summary: The SPDR Bloomberg 1-3 Month T-Bill ETF (BIL) performed exactly as expected for an ultra-low-risk investment proxy during the 2021-2025 period. It provided highly consistent, small positive monthly returns with minimal price fluctuation, as evidenced by its tight return distribution, extremely low standard deviation (~0.3%), and near-zero rolling volatility. Its price trend reflected stable capital preservation followed by steady accrual as short-term interest rates rose. BIL appropriately serves its function as a cash equivalent or risk-free benchmark for comparison in this analysis.

## REFFERENCES


[1] H. Markowitz, "Portfolio Selection," The Journal of Finance, vol. 7, no. 1, pp. 77–91, Mar. 1952.

[2] Z. Bodie, A. Kane, and A. J. Marcus, Investments, 12th ed. New York: McGraw Hill, 2021.

[3] E . J. Elton, M. J. Gruber, S. J. Brown, and W. N. Goetzmann, Modern Portfolio Theory and Investment Analysis, 9th ed. Hoboken, NJ: John Wiley & Sons, 2014. (Example source discussing risk-return plots)

[4] S. J. Taylor, Asset Price Dynamics, Volatility, and Prediction. Princeton, NJ: Princeton University Press, 2005. (Example source likely discussing price adjustments)

[5] J. C. Hull, Options, Futures, and Other Derivatives, 11th ed. Hoboken, NJ: Pearson, 2022. (Example source covering volatility concepts)

[6] R. F. Engle, "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation," Econometrica, vol. 50, no. 4, pp. 987-1007, Jul. 1982. doi: 10.2307/1912773R. Nicole, “Title of paper with only first word capitalized,” J. Name Stand. Abbrev., in press.

[7] R S. Tsay, Analysis of Financial Time Series, 3rd ed. Hoboken, NJ: John Wiley & Sons, 2010. (Example source for statistical properties)

[8] W. F. Sharpe, "The Sharpe Ratio," The Journal of Portfolio Management, vol. 21, no. 1, pp. 49–58, Fall 1994. doi: 10.3905/jpm.1994.409501.

[9] A. Damodaran, Investment Valuation: Tools and Techniques for Determining the Value of Any Asset, 3rd ed. Hoboken, NJ: John Wiley & Sons, 2012. (Example source for valuation/growth stocks)

[10] D. G. Baur and T. Dimpfl, "The volatility of Bitcoin and its role as a medium of exchange and a store of value," Empirical Economics, vol. 61, no. 5, pp. 2663–2683, Nov. 2021. doi: 10.1007/s00181-020-01990-5. (Example paper on Bitcoin volatility)

[11] A. Cheung, E. Roca, and J.-J. Su, "Crypto-currency bubbles: an application of the Phillips–Shi–Yu methodology on Bitcoin," Applied Economics, vol. 47, no. 23, pp. 2348-2358, 2015. doi: 10.1080/00036846.2015.1005827. (Example paper on Bitcoin cycles)

[12] F. J. Fabozzi, Bond Markets, Analysis, and Strategies, 9th ed. Hoboken, NJ: Pearson, 2016. (Example source for bond/interest rate risk)