All-Weather Risk-Parity Portfolio

Executive Summary

Just as important as identifying market regimes is the ability to navigate them through disciplined portfolio design and dynamic risk management. Inspired by Bridgewater Associates' foundational approach, an "all-weather" risk-parity portfolio aims to maintain stable performance across economic regimes by balancing risk contributions rather than capital weights. This project implements and rigorously evaluates such a portfolio using liquid, low-cost ETFs across diverse asset classes. Our objective is to validate the portfolio's construction in Python, analyze its historical behavior, and assess its resilience under extreme market stress.

This project begins by constructing a risk-parity portfolio using rolling volatility estimates to allocate daily weights across selected ETFs representing equities, fixed income, commodities, inflation protection, and cash equivalents. The portfolio is backtested over the past decade to quantify long-term return, volatility, Sharpe ratio, and drawdown.

Targeted stress tests are conducted during key crisis periods—the March 2020 COVID-19 crash, and the 2022 Russian-Ukraine conflict, and the 2025 Feb-April sell-off—to examine the portfolio's performance and risk mitigation characteristics. Additional analysis simulates extreme market shocks and computes full-history and rolling Value-at-Risk (VaR) and Conditional VaR (CVaR) metrics at 95% confidence.

Findings from this project not only confirm the expected behavior of risk-parity under stress, but also establish a reproducible Python-based backtesting and stress-testing framework. This lays the groundwork for integrating automated stress monitoring into our broader risk infrastructure. This project concludes with proposed enhancement of dynamic rebalancing to further improve robustness.

Methodology

This project is divided into three main phases: portfolio construction, historical backtesting, scenario-based stress testing, and shock simulation. Each phase is implemented in Python using a modular, reproducible framework with industry-standard libraries including pandas, numpy, and plotly. The adjusted closing prices that the project bases on are sourced from the yfinance API.

1. Portfolio Construction via Risk Parity

- *Asset Selection*: A diversified set of five liquid, low-cost ETFs was chosen to represent major asset classes:SPY—Equities, TLT—Fixed Income, GLD—Commodities, TIP—Inflation-protected bonds, and BIL—Cash equivalents
- *Volatility Estimation*: For each ETF, 126-day (6-month) rolling standard deviation of daily returns was calculated as a proxy for historical volatility.
- *Weight Calculation*: The risk-parity weight of the i^{th} ETF at date t was computed daily according to the following formula, $w_i(t) = \frac{1/\sigma i(t)}{\sum_{j=1}^{5} 1/\sigma j(t)}$, where $\sigma_i(t)$ = volatility estimate of the i^{th} ETF at date t.

2. Backtesting Performance

- *Return Calculation*: Daily portfolio returns are computed using daily adjusted prices and lagged weights (to avoid look-ahead bias). Cumulative returns were then calculated for visualization and metric derivation.
- *Performance Metrics*: Annualized Return, Annualized Volatility, Sharpe Ratio (assuming a 0% risk-free rate), Maximum Drawdown, and full-history and 252-day rolling Value-at-Risk (VaR) and Conditional VaR (CVaR) at the 95% confidence leve
- *Visualization*: An interactive equity curve and daily weight evolution were plotted using Plotly to illustrate portfolio behavior over time.

3. Stress Testing and Scenario Analysis

- *Historical Scenarios*: The portfolio's behavior is evaluated during the following stress periods: 2020 COVID-19 crash, 2022 Russian-Ukraine war sell-off, and 2025 Feb–April market drawdown.
- *Performance Metrics*: Cumulative return, peak drawdown, and recovery time

4. Shock Simulation

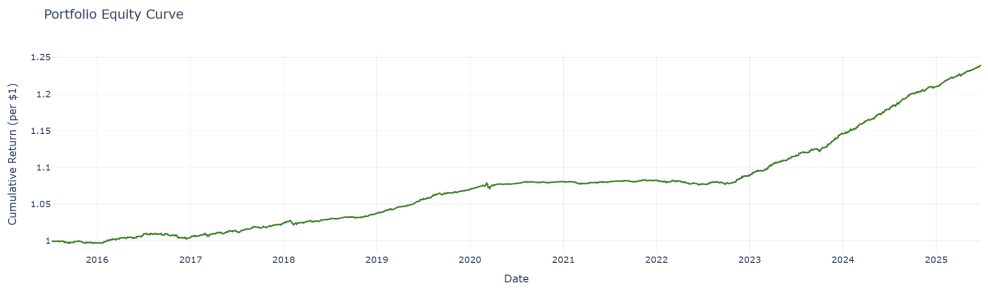
- *Extreme Shock*: A hypothetical simultaneous shock of –30% equity, +10% bond yields, –15% commodities was applied to assess first-day portfolio loss.

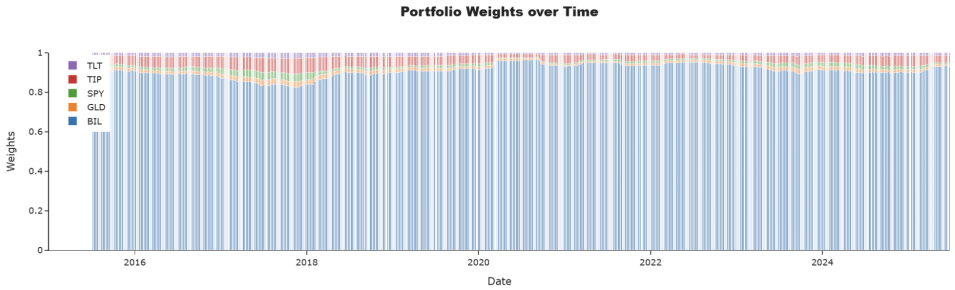
Results

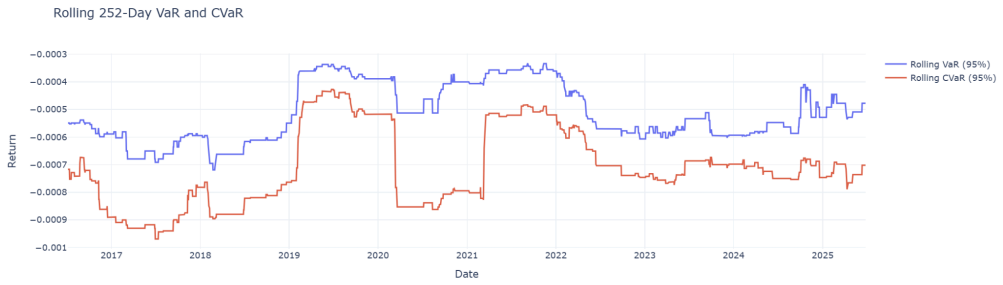
The following are the results of the risk-parity portfolio over a 10-year backtest period (e.g., July 2015 – July 2025).

Full-History Backtest Performance

Annualized Return	Annualized Volatility	Sharpe Ratio	Max Drawdown	Full-History VaR	Full-History CVaR
2.175%	0.616%	3.502	-0.759%	-0.054%	-0.075%

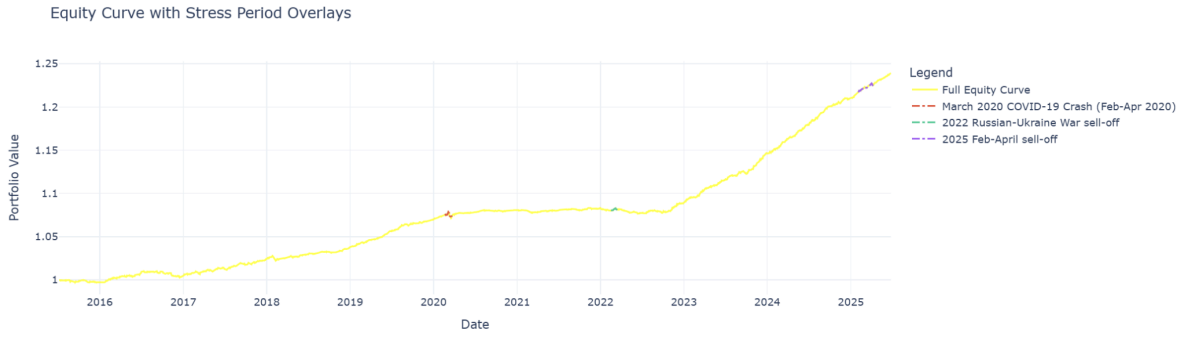






Stress-Period Scenario Analysis

Stress Event	Cumulative Return	Max Drawdown	Recovery Time (Trading Days)
2020 COVID-19 Market Crash (2020/02/19—2020/03/23)	-0.078%	-0.667%	1
2022 Russian-Ukraine War Sell-off (2022/02/16—2022/03/15)	0.041%	-0.173%	167
2025 Feb–April Market Drawdown (2025/02/01—2025/04/08)	0.600%	-0.243%	0



Shock Simulation

The hypothetical shock of –30% to equities, +10% to bond yields, and –15% to commodities resulted in a first-day estimated portfolio loss of 0.744%, highlighting the benefit of diversified exposure.

Discussion and Key Insights

The risk-parity portfolio exhibited *low volatility* and *smooth compounding* over time, resulting in a high Sharpe Ratio and strong alignment with its goal of *capital preservation*. The observed max drawdown was limited, consistent with expectations for a diversified multi-asset strategy. This performance stems largely from the portfolio's volatility-based weighting approach, which naturally *tilted allocation toward lower-volatility assets*—most notably the cash-equivalent BIL. In several periods, *BIL* accounted for up to 90% of the total portfolio, contributing significantly to *stability, minimal drawdowns, and fast recovery times*. The *equity curve showed consistently positive growth*, particularly in recent years, further validating the portfolio's conservative asset mix.

The *rolling Value-at-Risk (VaR)* and *Conditional VaR (CVaR)* remained *well-contained* with only modest upticks during volatile periods. Even in extreme cases, daily expected losses *stayed below –0.1%*, and *full-history VaR/CVaR hovered close to zero*—clear evidence that the *risk-parity portfolio tightly controlled tail-risk exposure* across regimes and crises.

The *largest drawdown* occurred during *the 2020 COVID-19 market crash*, where the risk-parity portfolio briefly experienced *negative cumulative returns*. Despite the diversified structure, *equities (SPY)* plunged as investors priced in a sudden *halt in economic activity*, and even *gold (GLD)* sold off temporarily due to widespread *panic and the urgent liquidity need*. In contrast, BIL (a cash-equivalent ETF) remained nearly flat—which suited investors' *need for capital stability* and acted as the critical ballast. The *fiscal stimulus and aggressive monetary easing* by central banks soon *restored market confidence*, and the portfolio recovered almost immediately, especially in risk assets.

In the 2022 Russia–Ukraine War, SPY again underperformed as market sentiment deteriorated under geopolitical tension and uncertainty. Long-term Treasuries (TLT) also fell sharply, reflecting a *sharp spike in real interest rates*, which often occurs when inflation fears outweigh the flight-to-safety demand. *Inflation was already elevated*, and the war aggravated global supply shocks, raising expectations of tightening monetary policy. As a result, bonds lost their usual defensive role. However, *GLD (gold), seen as a store of value*, and BIL, which continued to offer stability, became the primary stabilizers, helping the portfolio recover in approximately six months—the *longest recovery time* among the stress events.

During the 2025 Feb–April sell-off, triggered by aggressive *U.S. tariff hikes* and subsequent retaliations, *SPY* declined as concerns over *global trade disruption, rising input costs, and corporate earnings compression* took hold. Ahead of *an expected inflationary environment*, investors rotated into *TIP (inflation-linked bonds)* as protection, alongside *GLD* and *BIL*, which again demonstrated *resilience*.

Stress Event	Main Underperformer	Best Hedge
2020 COVID-19 Market Crash (2020/02/19—2020/03/23)	SPY, GLD	BIL
2022 Russian-Ukraine War Sell-off (2022/02/16—2022/03/15)	SPY, TLT	BIL, GLD
2025 Feb–April Market Drawdown (2025/02/01—2025/04/08)	SPY	BIL, TIP, GLD

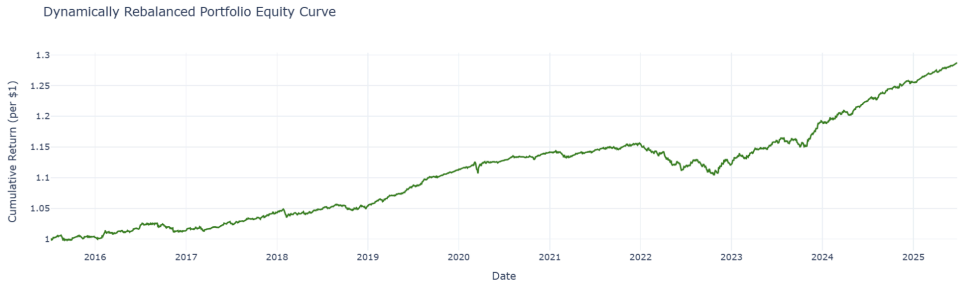
Importantly, the portfolio showed *no signs of regime failure*—a condition where all asset classes fall simultaneously. While cross-asset correlations did rise temporarily (especially in March 2020), the *risk-parity framework preserved diversification*, ensuring that *at least one or more uncorrelated assets* (often BIL or GLD) helped mitigate losses. This resilience confirms the effectiveness of *volatility-weighted allocation* in *reducing tail risk* and *preserving capital* across diverse economic regimes.

Enhancement Recommendation

One enhancement is to adopt a dynamic rebalancing strategy to the All Weather risk-parity portfolio weights rather than updating the weights daily solely according to the

assets' rolling volatility. Specifically, dynamic rebalancing takes into account macroeconomic indicators—Real GDP growth and FED Fund Rates—as forward-looking signals and adjusts portfolio allocation to better suit the evolving economic environment. Evidently, this enhancement increases the portfolio's risk exposure but offers higher overall returns.

Annualized Return	Annualized Volatility	Sharpe Ratio	Max Drawdown	Full-History VaR	Full-History CVaR
2.566%	1.522%	1.675	-4.454%	-0.152%	-0.221%



In the current framework, where portfolio allocation is adjusted daily based on assets' daily rolling volatility, the strategy already recognizes the non-staticity of market conditions and asset class behavior. It actively reviews allocations to maintain a stable risk profile while responding to volatility shifts. However, this adjustment is purely backward-looking. By layering in macroeconomic variables like GDP and FED rates, the portfolio seeks to anticipate market regimes (changes in economic growth and monetary policy) and proactively position itself to capture favorable opportunities while reducing exposure to adverse conditions. This enhances long-term risk-adjusted performance by selectively taking on greater risks.

Applied to the All Weather portfolio, this approach is especially advantageous given the differing sensitivities of equities, bonds, and commodities to growth and inflation. Dynamic rebalancing enables systematic adjustments—such as reducing equity exposure during economic contractions or shortening bond duration when interest rate hikes are expected. These forward-looking tilts can help the portfolio adapt to different market regimes, something a purely volatility-based approach may miss.

It's important to note that this enhancement shifts the traditional All Weather philosophy. Originally designed as a passive, long-term portfolio with fixed asset weights, introducing dynamic rules makes it more active in nature. However, the proposed dynamic model is rule-based—allocations are adjusted automatically based on predefined macroeconomic signals. In this sense, it maintains some of the appealing features of passive investing, such as discipline and minimal discretionary intervention, while potentially outperforming its static counterparts.

That said, one practical consideration is increased portfolio turnover. As weights shift in response to changing macro signals, more trades are executed, potentially leading to higher transaction costs—which may slightly reduce returns, particularly when trading costs are nontrivial. Therefore, any implementation of such a model should carefully weigh expected performance benefits against real-world trading costs and portfolio management complexity.

References

[Dynamic Rebalancing Model applied to the All Weather Portfolio — Giulio Siniscalco]