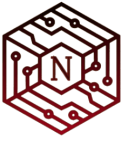


Multi-Strategy SAA Portfolio Analysis

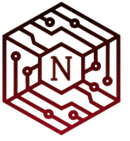
Author: Sanjeev Narasimhan

Date: 05/01/2024



Abstract

This paper explores quantitative investment management strategies through Python-based analysis, focusing on portfolio optimization and risk mitigation techniques. Drawing on data spanning January 2000 to July 2020, I evaluate the performance of diverse indexes and construct portfolios with tailored constraints to surpass benchmark returns while managing volatility. The study encompasses both long-term (20-year) and shorter-term (10-year) lookback periods to assess robustness, and by juxtaposing portfolio performances against traditional benchmarks such as the S&P 500 and a Rebalancing 60/40 Portfolio, we illustrate the efficacy of our optimization methodologies. Moreover, we investigate the performance of the Ray Dalio All Weather Portfolio, highlighting its role in diversification and stable returns across economic cycles. Lastly, we introduce a dynamic indicator leveraging VIX data to tactically switch between portfolio strategies during periods of market turbulence and economic uncertainty. This approach highlights the importance of adaptability in portfolio construction, offering insights into navigating volatile market environments and means by which to capture greater risk adjusted returns.



Optimized Strategic Asset Allocation

Motivation for Algorithmic SAA

While investment strategy may differ from investor to investor, in the context of portfolio construction, there are many aspects that must be determined early in the process before settling on portfolio construction including (but not limited to):

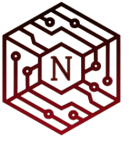
- Expected Returns
- Risk Tolerance/ Aversion
- Time Horizon (Short/ Medium/ Long)

Following this, the investor then must make the determination of what asset classes to include, as well as how much of the portfolio to allocate across them. While manual methods may be effective in generating alpha for seasoned investors, incorporating an algorithmic approach can aid in separating emotional biases and subjective judgment calls from decisions that may act as a barrier from generating greater alpha.

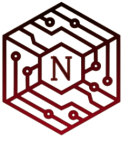
Index Data

The following data was collected through use of a Bloomberg Terminal as Cumulative Total Returns Gross Dividends and is used as the “Universe” of possible asset classes to allocate into:

- SPX (S&P 500 Index): S&P 500 tracks the performance of 500 large-cap companies listed on stock exchanges in the United States. It's considered a benchmark for the overall performance of the U.S. stock market
- LBUSTRUU (U.S. Aggregate Bond Index): The Bloomberg Barclays U.S. Aggregate Bond Index tracks the U.S. investment-grade bond market. It includes Treasury securities, government agency bonds, mortgage-backed bonds, corporate bonds, etc.



- SPGSCI (S&P GSCI Index): The S&P GSCI Index tracks the performance of a broad range of commodities, including energy, metals, agriculture, and livestock. It's a widely used benchmark for commodity investments.
- RMSG (Russell Midcap Growth Index): The Russell Midcap Growth Index measures the performance of mid-cap companies in the United States with a focus on growth-oriented stocks. It's a subset of the broader Russell Midcap Index
- LP01TREU (Pan European High Yield Bond Index): This index represents the performance of high-yield corporate bonds in Europe. It tracks non-investment-grade bonds issued by companies with lower credit ratings.
- TWSE (Taiwan Stock Exchange Index): The Taiwan Stock Exchange Weighted Index tracks the performance of stocks listed on the Taiwan Stock Exchange, and is a key benchmark for the Taiwanese equity market.
- IBOV (Ibovespa Index): The Ibovespa Index is the benchmark index for the Brazilian stock market. It tracks the performance of the most liquid stocks traded on the São Paulo Stock Exchange (B3).
- SASEIDX (Saudi Stock Exchange Index): The SASEIDX tracks the performance of stocks listed on the Saudi Stock Exchange (Tadawul), and is the primary stock market index for Saudi Arabia
- NKY (Nikkei 225 Index): The Nikkei 225 Index is Japan's premier stock market index, tracking the performance of 225 large, publicly traded companies listed on the Tokyo Stock Exchange.
- MXDK (MSCI Denmark Index): The MSCI Denmark Index measures the performance of large and mid-cap companies in Denmark's equity market. It's part of the MSCI Global Investable Market Indexes.
- SMI (Swiss Market Index): The Swiss Market Index tracks the performance of the largest/ most liquid stocks on the Swiss Exchange (SIX), and is a key benchmark for the Swiss equity market.
- VNINDEX (VN Index): The VN-Index is the benchmark stock index of the Ho Chi Minh Stock Exchange (HOSE) in Vietnam. It represents the performance of the Vietnamese stock market.



Primary Benefits of Index Inclusion

Diversification and Risk Mitigation

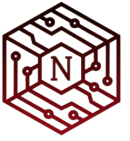
Incorporating the above indexes into our portfolio enhances diversification through exposure to a different geographic region/ currencies, asset classes, etc., reducing portfolio volatility and improving risk-adjusted returns. Furthermore, by incorporating indexes with low/ negative correlations, investors can further reduce portfolio volatility and minimize losses during market shifts.

Potential for Higher Returns

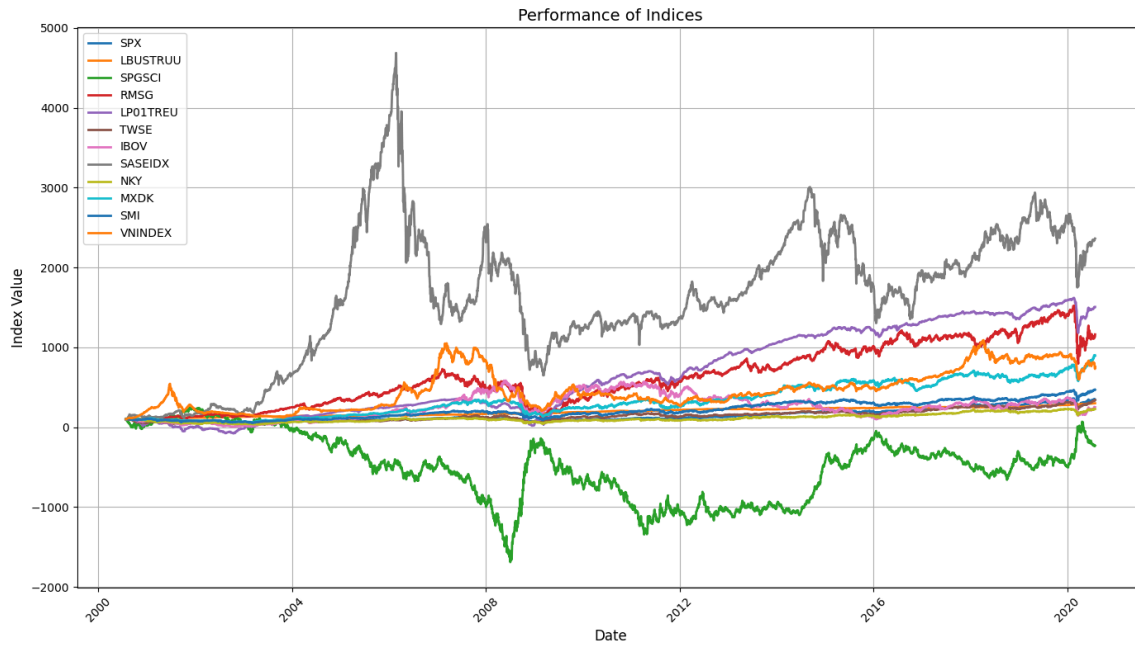
Historically, some indexes tend to perform better than others, and by incorporating these indexes into our portfolio, investors can enhance the portfolio's overall returns, as well as tap into economic growth potential of some of these markets.

Hedging

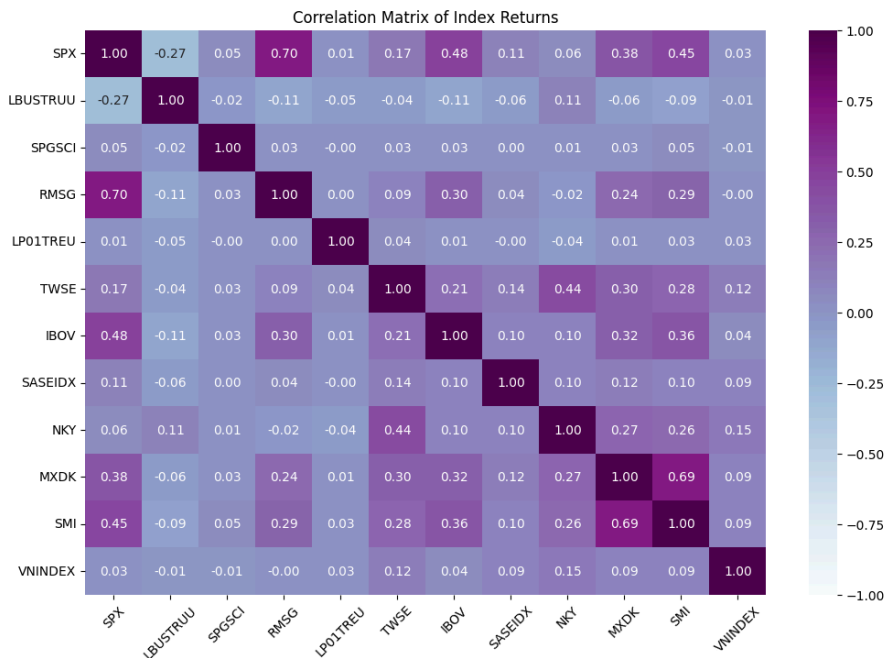
The inclusion of international equities in the portfolio provides a hedge against specific risks associated with the US market, such as regulatory changes, political instability, or economic downturns, reducing the portfolio's overall sensitivity to external shocks.

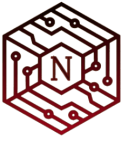


Historical Index Performance



Index Return Correlations





Portfolio Construction (SAA_I)

20 Year Lookback Optimization

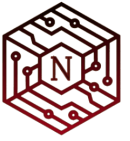
To determine the optimal allocation of our portfolio across the above indexes, we began with an equal weighted portfolio, and using an optimizer, determined the allocation that maximized the Sharpe Ratio over a 20 year period given the following goals and constraints:

Constraints

- Minimum Annualized Target Return $\approx 9\%$
 - Using the S&P as a benchmark for annualized returns, the Annualized 20 Year Return for the S&P (SPX) was $\approx 8.8857\%$. As such, we wanted our portfolio to generate competitive returns to the S&P.
- Maximum Annual Volatility $\approx 11\%$
 - Using the S&P and a Rebalancing 60/40 Portfolio as a benchmark for volatility, the Annual 20 Year Volatility for the S&P (SPX) was $\approx 20.1901\%$, and $\approx 11.2027\%$ for the 60/40. As such we wanted to end up with a portfolio that was generally less volatile than these benchmarks
- Maximum Allocation for any Index = 30%
 - To ensure that our portfolio is not too susceptible to economic/ country specific shocks, we set a cap on allocation such that no index can account for more than 30% of the portfolio.

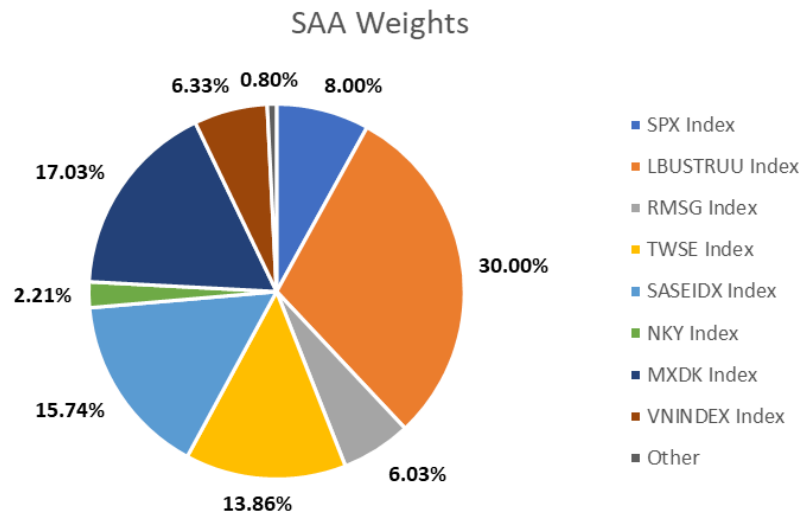
Goal

- Maximize the Sharpe Ratio
 - After the optimizer considers the above constraints, it then identifies the allocation that results in the highest Sharpe Ratio, or risk-adjusted relative returns



20 Year Optimization Results

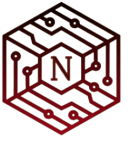
Index	Weights
SPX Index	8.00%
LBUSTRUU Index	30.00%
RMSG Index	6.03%
TWSE Index	13.86%
SASEIDX Index	15.74%
NKY Index	2.21%
MXDK Index	17.03%
VNINDEX Index	6.33%
Other	0.80%



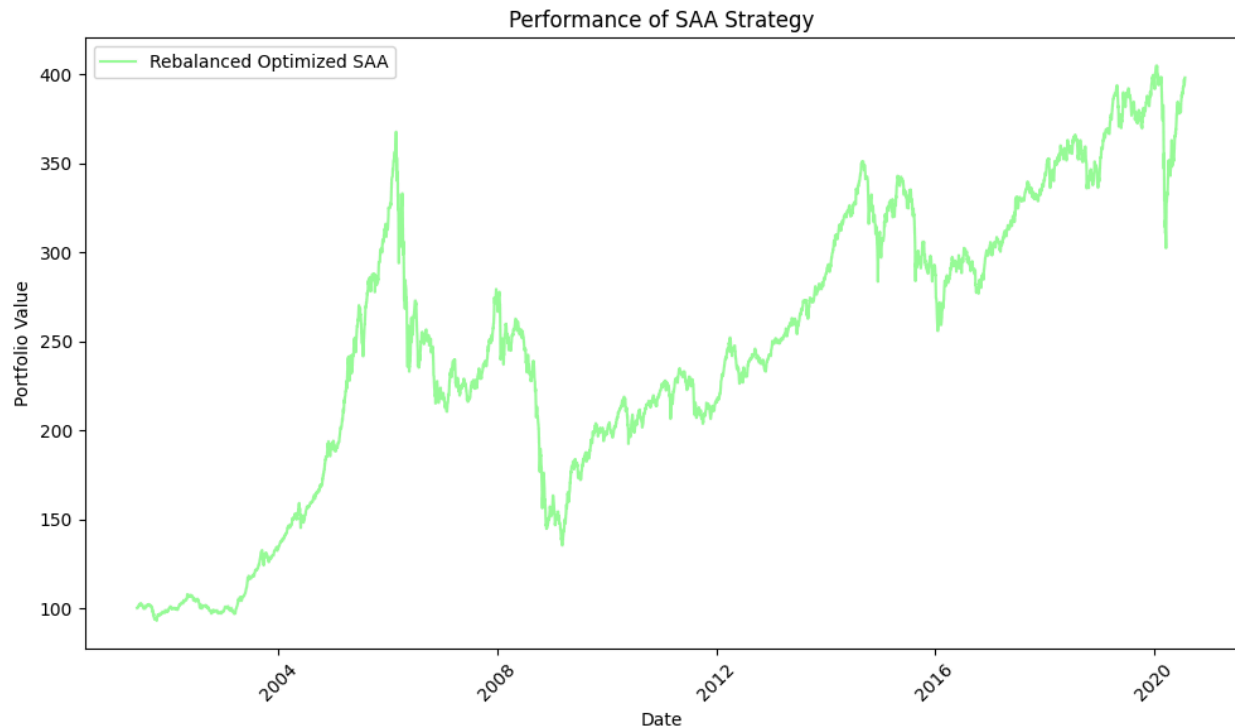
Under the optimizer, the above weights were determined to be most optimal, returning the following metrics:

- Expected Portfolio Return: 12.30%
- Expected Portfolio Volatility: 11.1%
- Sharpe Ratio: 1.108

It is important to note that these are expected values and are not necessarily accurate as to their actual performance over the 20 year period

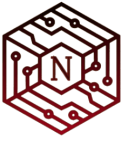


Visualizing Performance



	Annualized Return	Portfolio Beta	Sharpe Ratio	Volatility	Max Drawdown
Rebalanced SAA	7.87%	0.4013	0.5870	13.40%	-63.19%

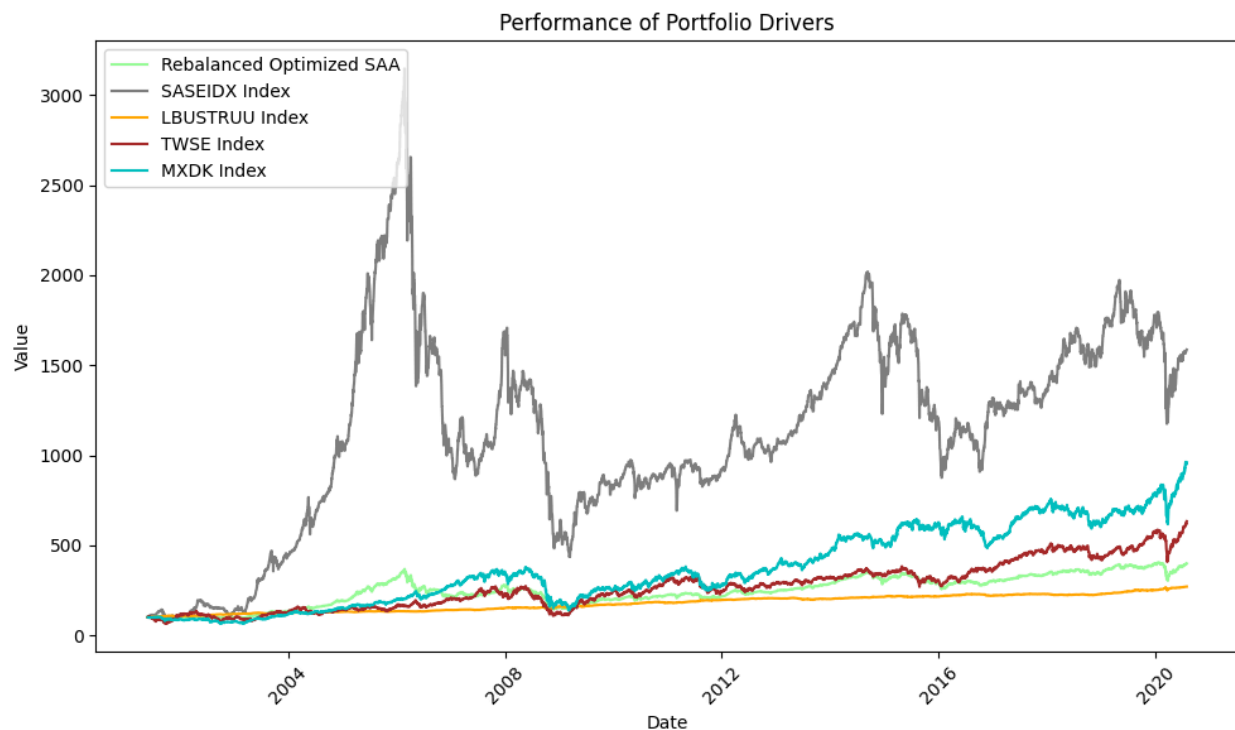
The above graphic and table visualizes the performance of the rebalancing optimized SAA over the course of 20 years given a starting portfolio value of \$100. As observable, the optimized SAA performed exceptionally well during the first ~6 years since inception, however, shortly after it experienced a significant loss in portfolio value in 2006, and then again in 2008. Furthermore, its growth gradually slowed down relative to its initial performance over the remaining years and ended with a final portfolio value of ~\$398. Implementing this strategy would have the investor take on a sizable amount of Volatility and experience a significant Max Drawdown in the process. While the Beta and Volatility of the portfolio is still relatively low, this is due to the fact that the returns of the indexes within the SAA allocation are not highly correlated (comparatively). As such this specific optimization strategy is not a viable means for consistent and alpha generation.



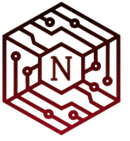
Portfolio Construction (SAA_2)

Reasons for Failure

When observing the portfolio performance of the original SAA, there are a couple aspects that clearly visualize/ justify the poor overall performance of the portfolio, which can be visualized by isolating the performance of the indexes that account for the majority of the SAA (LBUSTRUU, TWSE, SASEIDX, and MXDK).



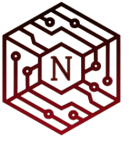
While the performance of most of these indexes were stable (relatively), the SASEIDX has been experiencing incredibly high fluctuations. Over the course of the 20 year period, the returns of the Saudi Arabia Stock Exchange outclassed its peers (due to the forming of a “bubble”) during the earlier years in this 20 year period, and as such the optimizer granted a sizable allocation into this. This spiked the growth of the SAA earlier into its life, however the collapse of the Saudi stock market in 2006 (“Black February”) slashed the value of this investment, leaving a highly volatile index as a core allocation in the portfolio.



10 Year Lookback Optimization

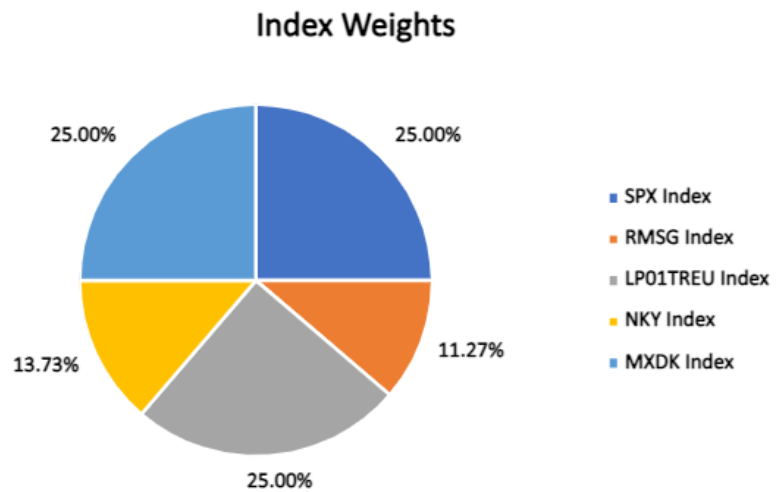
Rather than zero out a specific index based on a particular period of its historical performance, an iteratively expanding window filter was applied to the dataset in intervals of 2 years. In this the optimizer would train on the previous N years worth of data and then the determined allocation would be tracked over the full 20 year period.

This filter was applied to train on a lookback periods of 2, 4, 6, ..., 16, 18, and 20 years, returning the different optimized allocation given the same constraints as before, the only exception being that the allocation cap would be lowered to 25% to better diversify investments. From this the largest lookback period would be selected that would grant a more equal playing field to the different indexes while also providing a considerable amount of data to train off of. A 10 year lookback training window was selected as its starting point would occur during a time of relatively stable performance across the indexes. Increasing the lookback period by 2 more years would start the training during the great recession, and any further would take the optimizer back to the collapse of the SASEIDX. As such, the 10 year window was selected as the lookback period to train the optimizer on and will be used for the remainder of this paper.



10 Year Optimization Results

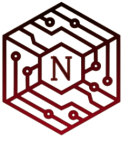
Index	Weights
SPX Index	25.00%
RMSG Index	11.27%
LP01TREU Index	25.00%
NKY Index	13.73%
MXDK Index	25.00%



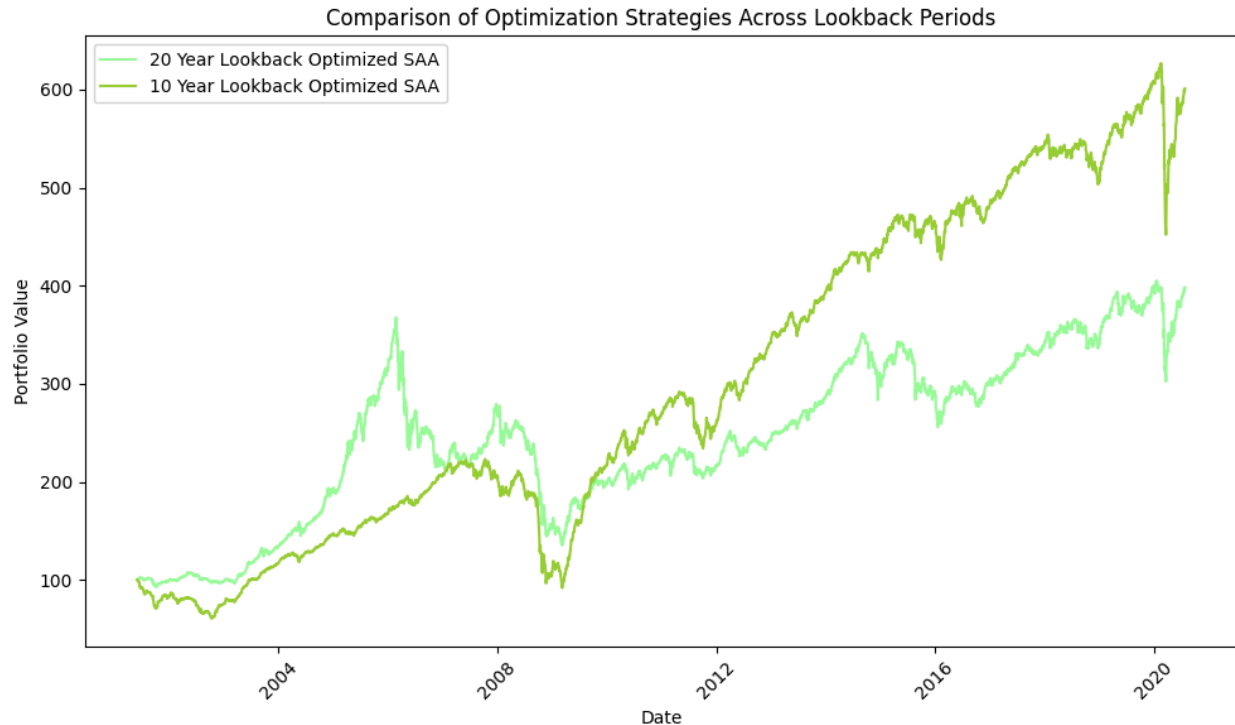
Under this new optimization, the above weights were determined to be most optimal, returning the following metrics:

- Expected Portfolio Return: 12.78%
- Expected Portfolio Volatility: 12.0%
- Sharpe Ratio: 1.06

It is important to note that these are expected values and are not necessarily accurate as to their actual performance over the 20 year period

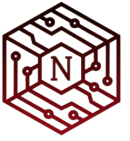


Comparing Performance of Different Lookback Periods



	Annualized Return	Portfolio Beta	Sharpe Ratio	Volatility	Max Drawdown
Rebalanced SAA1	7.87%	0.4013	0.5870	13.40%	-63.19%
Rebalanced SAA2	9.59%	0.6219	0.9057	10.59%	-58.78%

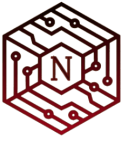
The above graphic visualizes the performance of our new optimized strategy using a 10 year lookback period compared to the original 20 year lookback strategy. As observable, not only does this newly optimized strategy generate greater returns than its predecessor, it is able to do so with far less volatility and fluctuation in the overall portfolio value. While its predecessor ended with a portfolio value of ~\$398 over the 20 year period, the newly optimized portfolio after 20 years was able to generate ~\$601 from a \$100 starting investment. As shown in the table, this strategy is able to generate ~1% greater Annualized Returns, a higher Sharpe Ratio, a reduction in Volatility, and a lower Δ (Max Drawdown) for an ~0.2 increase in Beta. As such, these performance metrics, coupled with the far more stable performance over the 20 year period make it a strong strategy to move forward with.



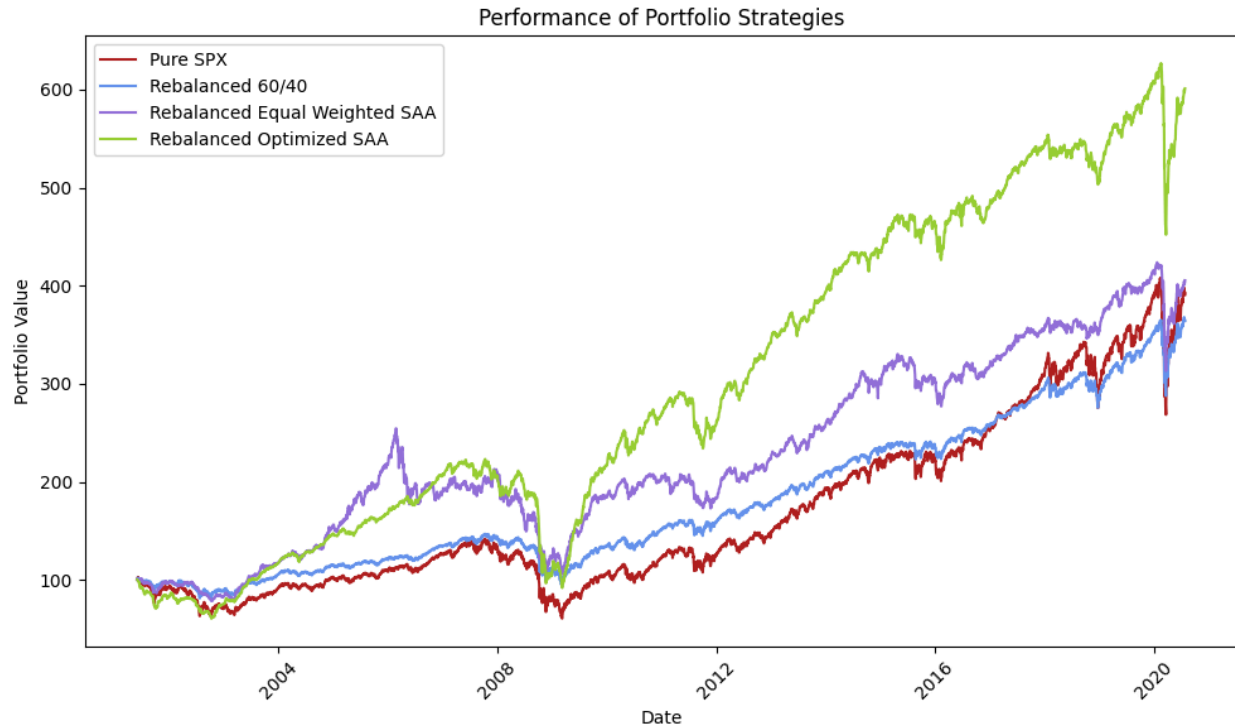
Portfolio Strategy

In the content of SAA Portfolios, the effectiveness of the strategy comes from maintaining the optimal allocation, and as such rebalancing periods are commonly used to maintain the benefits that arise from strategic asset allocation. For the purposes of this portfolio, we will be using a quarterly rebalancing strategy where we rebalance and reallocate the total portfolio value on the first of January, March, June, and September. This same rebalancing strategy was applied to the following portfolio allocation strategies:

- Pure SPX
 - To properly gauge the effectiveness of our strategy we want to compare our performance to a strategy of only investing in the S&P, as we want to see whether or not there are higher returns to be found if we diversify from the S&P
- Rebalanced 60/40
 - A rebalanced 60/40 is a common benchmark to gauge the performance of an portfolio strategy as it has historically been able to generate competitive returns over the long term while reducing the volatility of the portfolio. As such is has been the standard strategy for investors with a moderate risk tolerance.
- Rebalanced Equal Weighted SAA
 - To properly gauge the performance of our optimized allocation strategy, we can compare its performance to one in which our portfolio equally weights the indexes. This will allow us to see if using the optimizer with the above constraints resulted in performance better/worse than if we did not.
- Rebalanced Optimized SAA (Our Strategy)



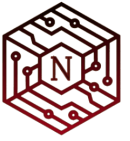
Gauging Metrics



	Annualized Return	Portfolio Beta	Sharpe Ratio	Volatility	Max Drawdown
Pure SPX	8.89%	1.7819	0.4401	20.19%	-57.10%
Rebalanced 60/40	7.11%	1.0000	0.6351	11.20%	-36.15%
Rebalanced EW SAA	7.87%	0.5202	0.6155	12.79%	-58.34%
Rebalanced SAA	9.59%	0.6219	0.9057	10.59%	-58.78%

The graph above shows the historical growth of a \$100 investment into the different investment strategies. When we consider the SPX (Red), the benchmark 60/40 portfolio (Blue), and the equal weighted SAA (Purple), our newly optimized SAA Portfolio (Green) strongly outperforms the benchmarks and the SPX. This tells us that by modifying a pure S&P or 60/40 portfolio and looking outside of the US, we can capture some of the returns to be found in the indexes of markets with strong economies and growth.

Considerations Regarding Metrics:

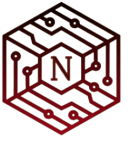


- *The Beta of a portfolio is calculated with respect to the benchmark Rebalancing 60/40*
- *The Sharpe Ratio assumes a Risk Free Rate of 0%*

Relative to the Rebalancing 60/40 and Pure S&P portfolio benchmarks (respectively), the 10 year lookback optimized SAA:

- Generated Greatest Annualized Returns at ~9.59% VS. ~7.11% & ~8.89%
- Operated at a Low Beta at ~0.6219 VS. 1.0 & ~1.7819
- Achieved the Highest Sharpe Ratio at ~0.9507 VS. ~0.6351 & ~0.4401
- Operated at the Lowest Volatility at ~10.59% VS. ~11.20% & ~20.19%
- Suffered the Highest Δ (Max Drawdown) at ~58.78% VS. ~36.15% & ~57.10%

The above metrics indicate that this optimized SAA performed exceptionally well relative to both the 60/40 and Pure S&P Benchmark. The portfolio was able to generate considerably higher annualized returns (9.59%) relative to the benchmarks, and was able to do so with far less risk (Beta of ~0.6219). While these metrics indicate a strong portfolio that is able to generate high and relatively stable returns over a longer time horizon, the portfolio does still suffer a high Max Drawdown (~58.78% portfolio loss). This high max drawdown, while still less than a Pure S&P portfolio, is still a cause for concern for a long term portfolio strategy, and as such is something that must be addressed.

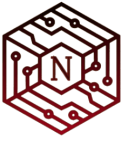


Ray Dalio All Weather Portfolio

Understanding the Strategy

The Ray Dalio All Weather portfolio, created by billionaire investor Ray Dalio, is a strategic asset allocation strategy designed to perform well across various economic environments, and is rooted in the principles of diversification and risk parity (Andreas et al., 2021). The primary purpose of the All Weather portfolio is to provide consistent returns regardless of economic conditions by diversifying across asset classes that have historically exhibited low correlation with each other. This strategy is implemented through the following asset classes and allocations:

- 30% Allocation to US Stocks
 - To capture the potential for long-term growth, the portfolio includes a significant allocation to equities.
- 55% Allocation to US Government Bonds
 - 40% Allocation to Long Term Bonds
 - 15% Allocation to Intermediate Term Bonds:
 - Bonds are included to provide stability and income to the portfolio.
- 15% Allocation to Hard Assets
 - 7.5% Allocation to Commodities
 - 7.5% Allocation to Gold
 - Hard Assets are included as a hedge against inflation and currency devaluation

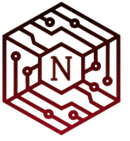


Replicating the Strategy

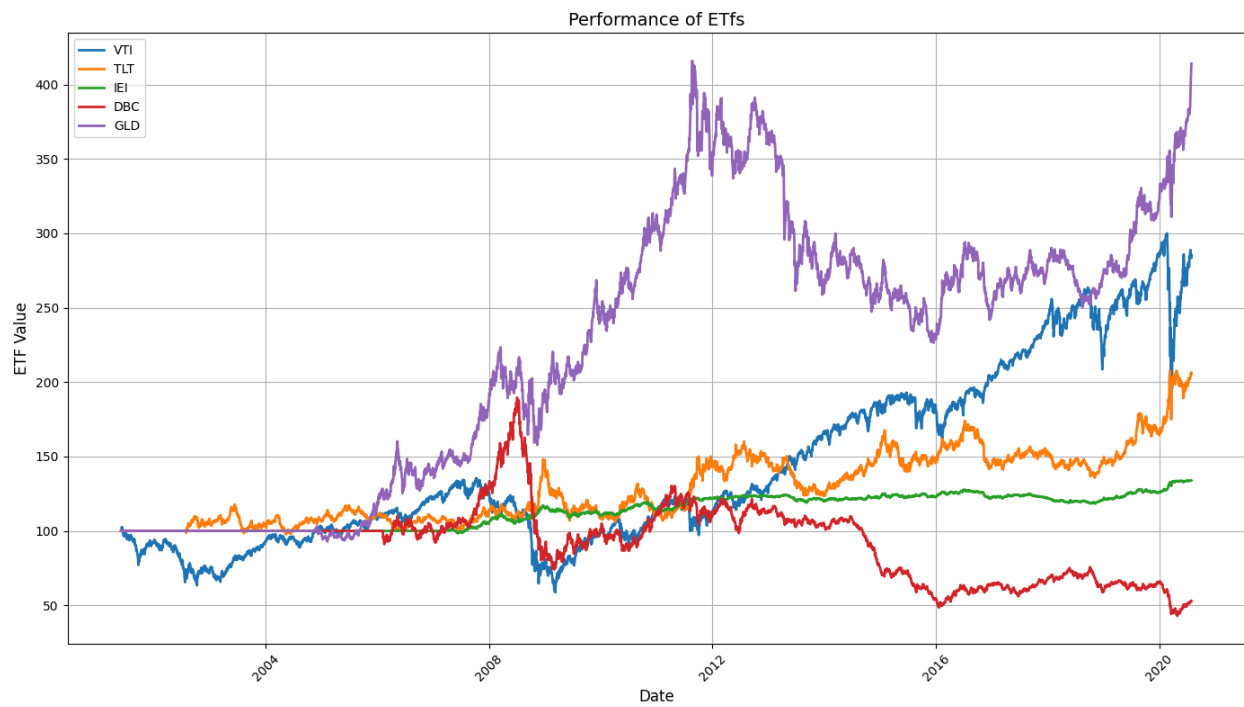
ETF Data

The following Price data was collected through use of a Bloomberg Terminal and represents the asset classes that will be used to replicate the Ray Dalio All Weather Portfolio:

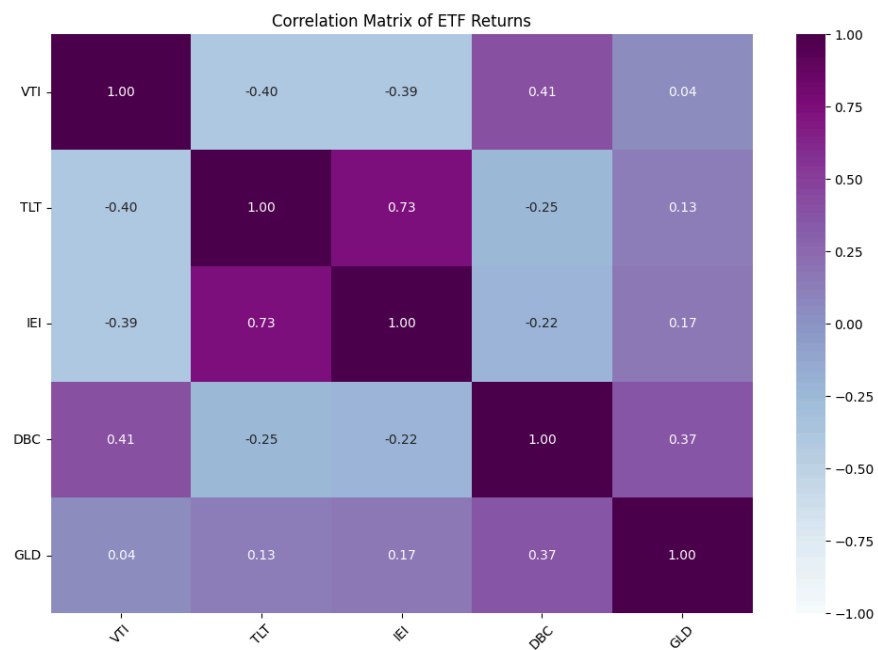
- VTI (Vanguard Total US Stock Market): VTI tracks the performance of the CRSP US Total Market Index, and includes large, mid, and small-cap equities
- TLT (iShares 20+ Year Treasury Bonds): TLT tracks the investment results of an index composed of U.S. Treasury bonds with remaining maturities greater than twenty years
- IEI (iShares 3-7 Year Treasury Bonds): IEI tracks the investment results of an index composed of U.S. Treasury bonds with remaining maturities between three and seven years.
- DBC (Invesco DB Commodity Index): DBC tracks an index of 14 commodities including Energy, Precious Metals, Industrial Metals and Agriculture sectors via futures contracts
- GLD (SPDR Gold Shares): GLD seeks to achieve the performance of gold bullion less the expenses of the Fund, and is designed as a cost effective way for investors to access the gold bullion market

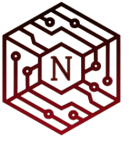


Historical ETF Performance



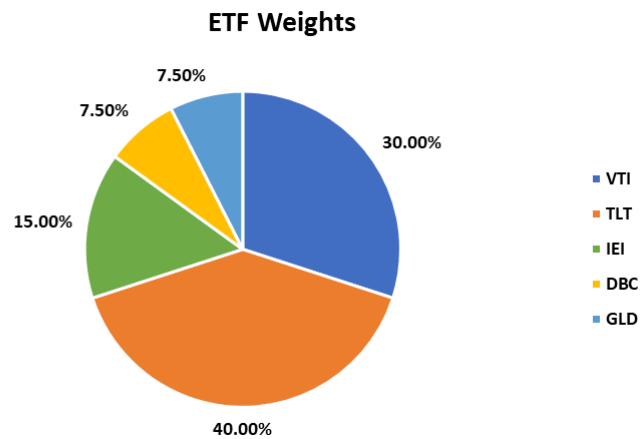
ETF Return Correlations



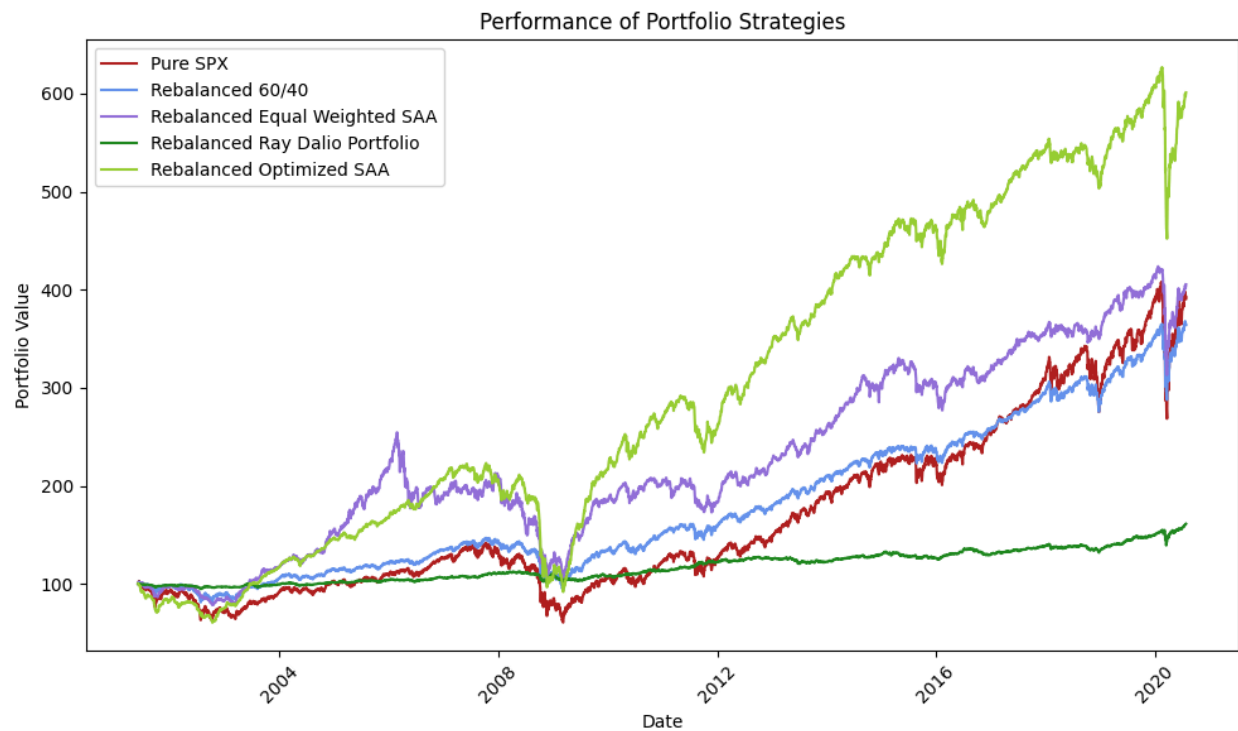


Portfolio Construction (All Weather Portfolio)

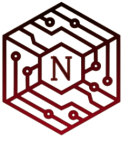
ETF	Weights
VTI	30.00%
TLT	40.00%
IEI	15.00%
DBC	7.50%
GLD	7.50%



Gauging Metrics



	Annualized Return	Portfolio Beta	Sharpe Ratio	Volatility	Max Drawdown
Pure SPX	8.89%	1.7819	0.4401	20.19%	-57.10%
Rebalanced 60/40	7.11%	1.0000	0.6351	11.20%	-36.15%
Rebalanced EW SAA	7.87%	0.5202	0.6155	12.79%	-58.34%
Rebalanced Ray Dalio	2.62%	0.2001	0.6424	4.08%	-10.20%
Rebalanced SAA	9.59%	0.6219	0.9057	10.59%	-58.78%



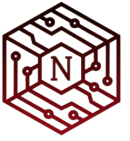
Note that the same implementation methods as before were used to track the performance of the All Weather Portfolio (\$100 Initial Investment & Quarterly Rebalancing), however with the ETFs we are working with Price data rather than Cumulative Total Returns Gross Dividends

The graph above shows the historical growth of a \$100 investment into the different investment strategies. When we consider the SPX (Red), the benchmark 60/40 portfolio (Blue), the equal weighted SAA (Purple), and the optimized SAA Portfolio (Green), the Ray Dalio All Weather portfolio clearly shows its merits as a strategy that can brave changes in economic conditions

Since the purpose of the All Weather Portfolio is to supplement our primary strategy, in times of economic downturn, relative to the 10 year lookback optimized SAA and the Rebalancing 60/40 strategies (respectively) the All Weather Portfolio:

- Generated Lowest Annualized Returns at ~2.62% VS. ~9.59% & ~7.11%
- Operated at the Lowest Beta at ~0.2001 VS. ~0.6219 & ~1.0
- Achieved a Low Sharpe Ratio at 0.6424 VS. ~0.9507 & ~0.6351
- Operated at the Lowest Volatility at ~4.08% VS. ~10.59% & ~11.20%
- Suffered the Lowest Δ (Max Drawdown) at ~10.20% VS. ~58.78% & ~36.15%

The above metrics indicate the All Weather strategy holds true to its claims. While it generated far lower returns than the optimized SAA and even the Rebalancing 60/40, that is not necessarily a metric that we were trying to maximize. The purpose of researching the All Weather strategy is to determine whether it truly could brave differing economic conditions using Beta, Volatility, and Max Drawdown as the determinants. The All weather strategy was able to perform at a far lower beta and volatility relative to its benchmarks, and most importantly, suffered a far lower loss in total portfolio value (~10.20% VS. ~58.78% & ~36.15%). As such, we can use this strategy to supplement the optimized SAA during periods of economic recession.



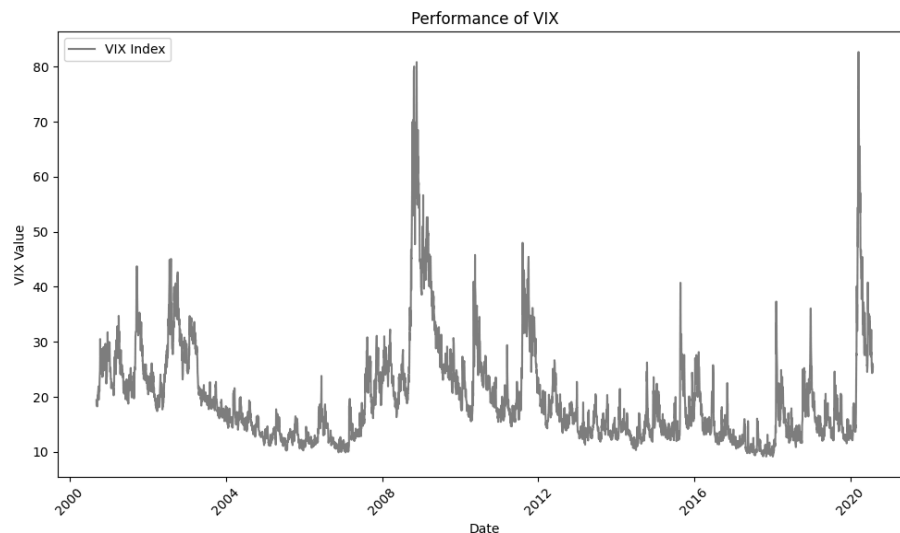
Analysis of VIX as Economic Indicator

Understanding the VIX

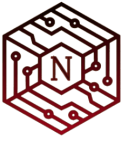
The CBOE Volatility Index (VIX), is a real-time market index representing the market's expectation of 30-day forward-looking volatility of the S&P 500 index options. The VIX is often used as a measure of investor sentiment and market risk, and as such is known by another name as the “Fear Index”. When the VIX is high, it suggests that investors expect significant market volatility or uncertainty, while a low VIX indicates expectations of relatively calm market conditions.

Using the VIX as an Indicator

For the purposes of our portfolio, the intention is to recognize when the market is entering a period of uncertainty (recession), and reallocate our portfolio using a strategy that is more resistant to economic shocks (Ray Dalio All Weather Strategy).

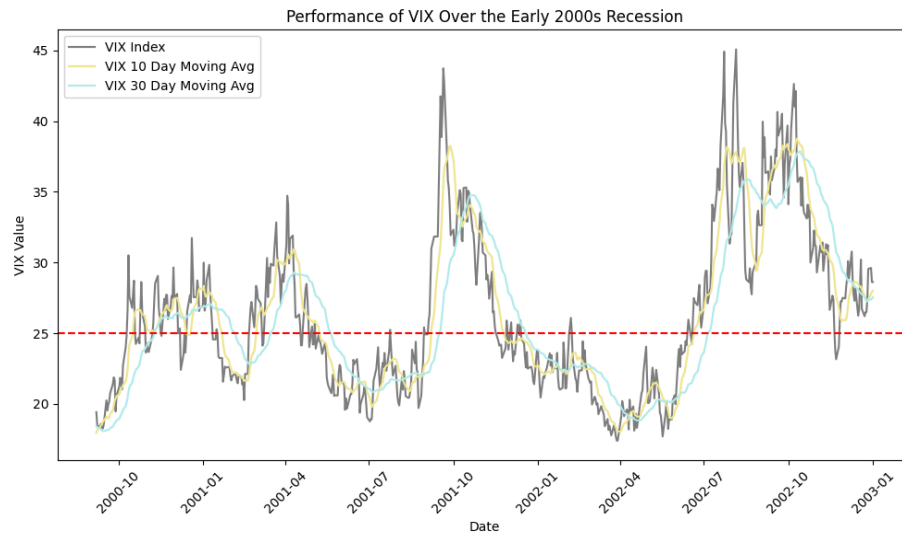


To begin this we can look to historical events that hurt/ slowed down the US economy and brought it to a recession: The Early 2000s Recession, The Great Recession, and the COVID Recession. By looking at the daily value of the VIX, its 10-Day, and 30-Day Moving Average, we can determine



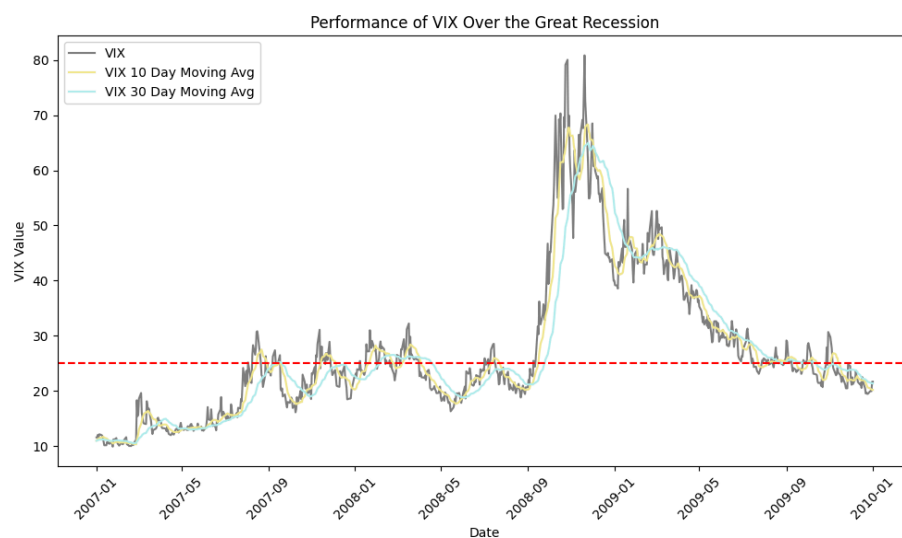
whether or not there exists a “clear” threshold at which the indication of entering into a recession/depression is strongest.

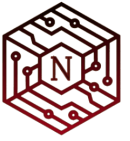
Early 2000s Recession



Looking at the above chart, we can observe the changing of the value of the VIX from the end of the year 2000 through the beginning of 2003. The effects of the Early 2000s Recession were most prominent from March of 2001 through November of 2001, which is not entirely clear when looking at the VIX chart.

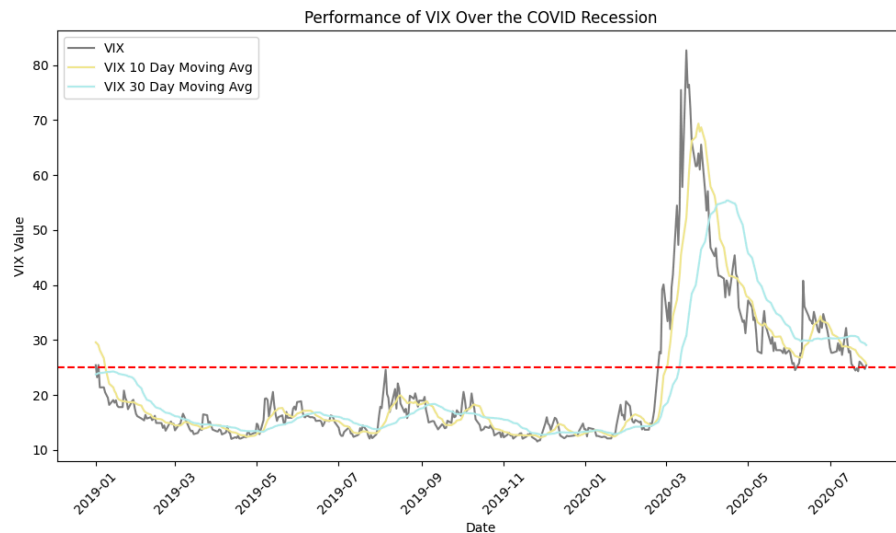
The Great Recession





Looking at the above chart, we can observe the changing of the value of the VIX from the beginning of the year 2007 through the beginning of 2010. The effects of the Great Recession were most prominent from December of 2007 through June of 2009, which is far more observable.

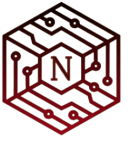
The COVID Recession



Looking at the above chart, we can observe the changing of the value of the VIX from the beginning of the year 2019 through the end of 2020. The effects of the COVID Recession were most prominent from February of 2020 through April of 2020, which is by far the most observable trend out of the 3 recessions considered.

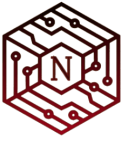
Setting Baseline for VIX as Indicator

To ensure that our indicator is not triggering at unnecessary points in time, we can set a threshold that aligns with the most prominent spikes in the VIX. The red line in the above graph illustrates this as a threshold of 25 is set. If the VIX is above 25, we believe that the market will experience a downturn, and if below 25, we believe it to be normal.



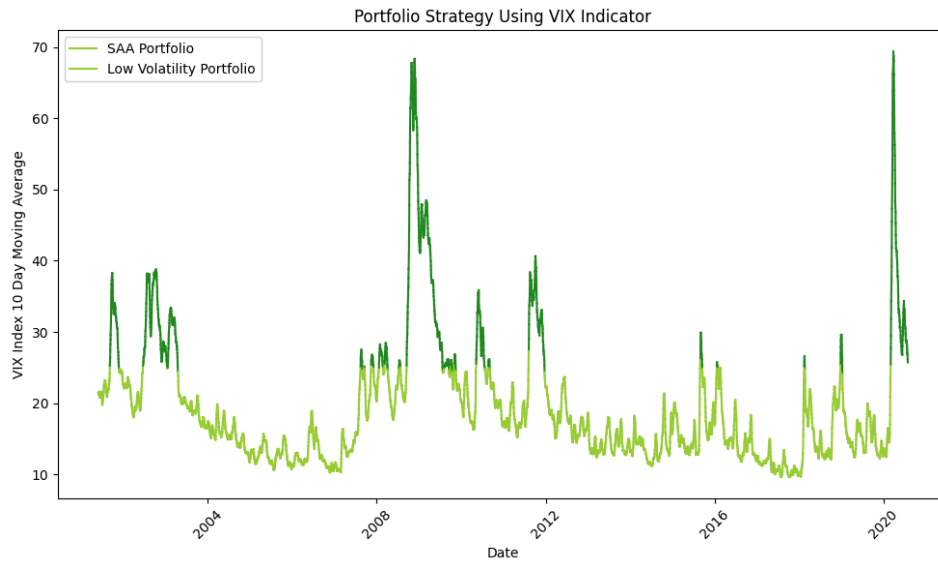
This threshold was determined by iteratively increasing the threshold value in increments of 1 from 20 to 30, and by calculating the number of times the VIX, its 10-Day, and 30-Day Moving Average breaches it. If the threshold is breached too often, the portfolio would continuously “lose value” through increased transition costs to change allocations more often or even lose out on the potential returns from using the optimized SAA. If the threshold is rarely breached, we may be more susceptible to shifts in the economy because the indicator may deem it to be not as serious of an event. Using this the optimal threshold level was determined to be at a value of 25, as the 10-Day Moving Average of the VIX did not breach this too often, and even with an additional 10 day delay, it is able to capture shifts relatively earlier on.

If we use the above threshold with the VIX, we can see that it would trigger our indicator very often, whereas the moving averages smoothe out the spikes. To best capture this while not lagging too far behind our indicator, we will use the 10-Day Moving Average as shown in light blue.

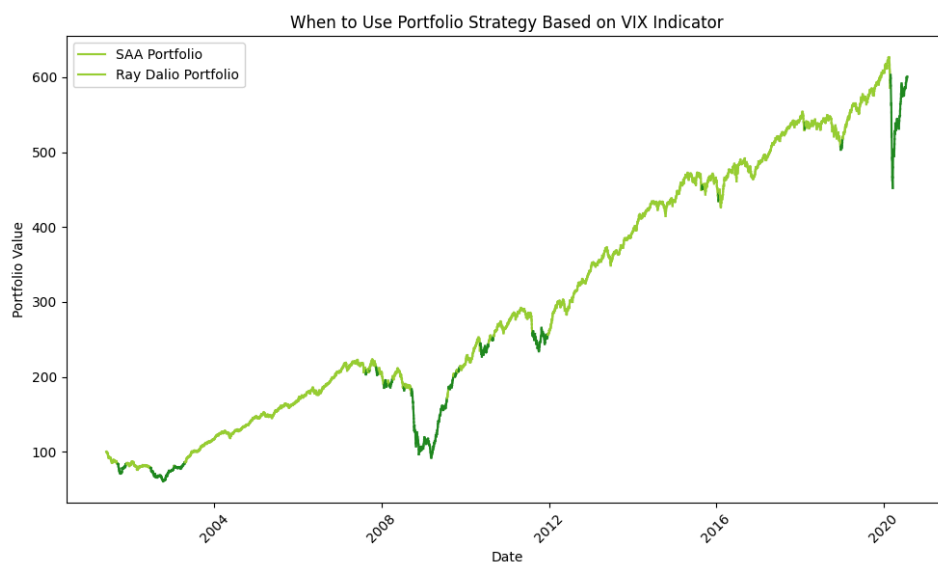


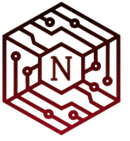
Incorporating Indicator into Portfolio Strategy

Effect of VIX Indicator on SAA Portfolio

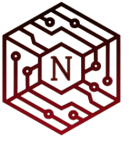


The above chart visualizes when the VIX indicator would trigger overlaid on the VIX performance over the course of 20 years. Looking at the above chart, this threshold using a 10-Day Moving Average is able to capture some of the spikes in the VIX, which would indicate that we should change portfolio strategies.





The above chart now overlays VIX indicator with our SAA Portfolio. As shown in the chart, by incorporating the VIX indicator into the optimized SAA, the strategy would be able to avoid some of the periods in time where the portfolio experiences a significant drop in value (Great Recession & COVID Recession). It is important to note that this indicator does not allow us to be able to avoid all instances of high drawdowns, but as a preliminary approach it holds its merit.



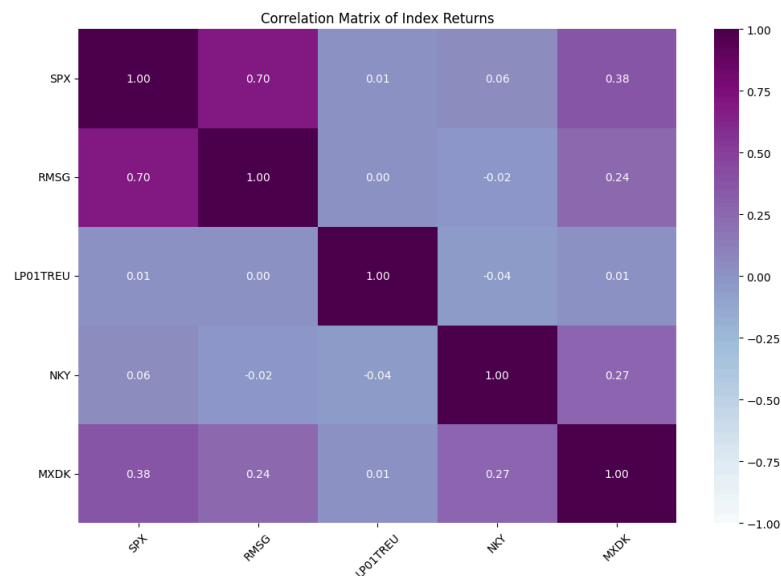
Next Steps

For this strategy to be viable in the long run there are 3 key areas that need to be fine tuned: the overall Investment Strategy, the VIX Indicator, and Using the Indicator.

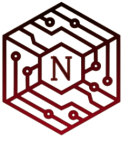
Fine Tuning Investment Strategy

Re-Optimizing Allocations

While the optimized SAA performs exceptionally well relative to its benchmarks, there are still some key (potential) issues that need to be addressed. First and foremost, the optimal allocation is not as diversified as it could be as our portfolio is distributed across 5 indexes. Within this, 36.27% of the index comes from the US, 25% from Denmark, 13.73% from Japan, and an additional 25% from European Bonds. Furthermore, the returns of the SPX, RMSG, and MXDK are relatively highly correlated, and as such, the overall portfolio is still susceptible to economic shocks within the US.



To fine tune this approach of optimal allocation, the strategy should also consider capping the amount of a portfolio that can be allocated to a specific country. By doing this the portfolio's resistance to economic shocks can be increased and in turn its resistance to high Max Drawdowns.



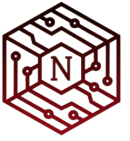
Within Index Optimization

While the optimized SAA performs very well relative to its benchmarks, a core aspect of the strategy is to minimize Volatility and Beta. Through the optimization, an investor can have a baseline of their potential returns if they track the performance of these indexes through ETFs, however, index performance is (at many times) driven by a subset of the actual index. To capture this potential alpha, the optimized allocations can instead act as a baseline for country-specific equity investments, in which other strategies can be adopted to maximize index specific returns (within the SPX, NKY, and MXDK). Based on the risk tolerance of the investor, the strategy could be shifted to adopt a factor-based strategy such as momentum for their investments into the respective equity indexes to capture returns from securities that move the index performance the most. By incorporating strategies such as these within the baseline index allocations, investors can try to capture higher returns and “beat” the respective indexes, while still operating under the baseline optimization for minimized Volatility and Beta.

Fine Tuning Indicator Strategy

When observing the VIX indicator strategy overlayed on the portfolio performance, it is clear that it is effective at minimizing Max Drawdowns, and is an effective indicator of economic recessions. However, it is important to note that the effectiveness of this indicator is most prominent in indexes based in the US. While some economic shocks based in the US have observable effects in overseas countries, the VIX’s predictive power as a “Fear Gauge” may not be effective as an indicator of overseas economic shocks. To fine tune the VIX approach we should also consider the volatilities in international markets, specifically those that we are heavily invested in. By using multiple volatility indicators we can shift our portfolio construction/ allocation to adapt to changes/ expected changes in international markets.

Unlike the VIX, there isn’t a similar index that tracks the volatility of international equity markets. Furthermore, it can be especially challenging to mimic the calculation of the VIX which is done by averaging the weighted prices of out-of-the-money puts and calls. A potential solution to this is by creating



a Synthetic VIX that is able to replicate the trends and movement of the VIX across different economic cycles and shifts.

In “Replicating the CBOE VIX using a synthetic volatility index trading algorithm”, Cary and van Vuuren discuss the effectiveness of two proposed synthetic VIX alternatives and how accurate they are in replicating the CBOE VIX.

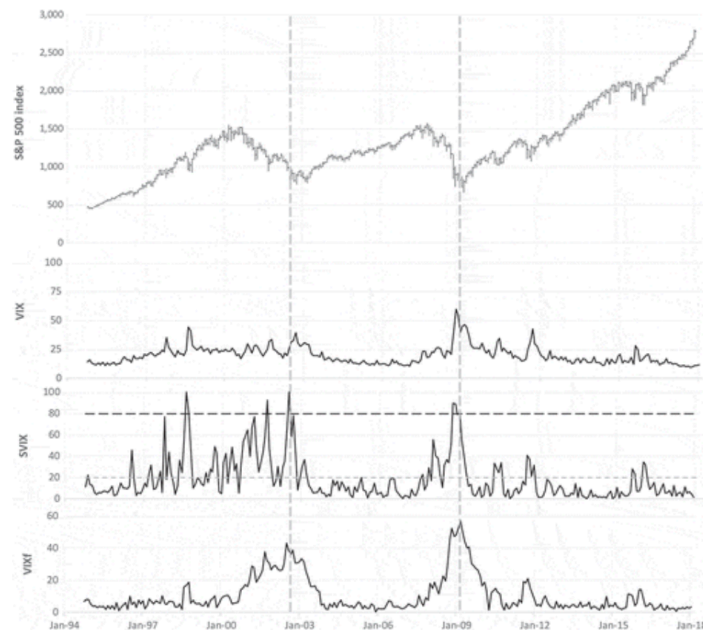
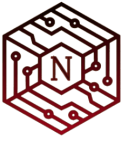
The first of the two alternatives, VIX fix (VIX_f) allows volatility to be plotted against any variable which has price data. It is effectively a synthetic VIX which allows the VIX to be duplicated on anything from treasury bonds to soybean futures as it is based on prior price information rather than future option prices (Cary & van Vuuren, 2019). It is calculated by subtracting the current Low Price from the Highest Close Price over the past 20 days, and dividing that difference from the Highest Close Price over the past 20 days.

$$VIX_f : \frac{(\text{Highest}(\text{Close},20) - \text{Low})}{(\text{Highest}(\text{Close},20))} \times 100$$

The second alternative, Stochastic VIX (SVIX) follows a similar process to the VIX_f , but also allows for the ability to explore momentum and the highest high/lowest low range of prices relative to the closing price over a prescribed period. It is calculated by subtracting the Lowest Value observed from the Current Close Price, and dividing that by the difference between the Highest High and Lowest Low Prices.

$$SVIX : \frac{\text{Current Close} - \text{Lowest Low}}{\text{Highest High} - \text{Lowest Low}} \times 100$$

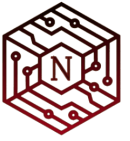
The paper calculated and tracked the performance of these synthetic VIXs for the S&P 500 over the same time scale and created the below visual showing (from top to bottom) the performance of the S&P, the VIX, the SVIX, and VIX_f :



As observable the synthetic VIXs track the performance/ trends of the VIX particularly well, returning the following correlations:

- SVIX: VIX 0.76
- VIX: VIXf 0.81

In moving forwards with using a VIX indicator, it could be effective to replicate the VIX_f for the different indexes that the SAA is allocated across and use it as an additional indicator (similar to what was done with the VIX). In doing we the portfolios strategy can look at country-specific volatility in equity markets to determine whether its respective economy is entering into a period of uncertainty or downturn, and whether or not the SAA strategy should be supplemented with an alternative (All Weather Portfolio)



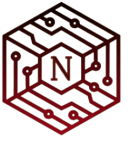
Using the Indicator

Another aspect of the investment strategy to consider when incorporating the indicator is how we would be supplementing the baseline SAA strategy. Earlier in the paper the Ray Dalio All Weather Portfolio was selected as the alternate strategy to supplement the baseline when the indicator was triggered. While this strategy would be helpful to generate stable returns and reduce $\Delta(\text{Max Drawdown})$, this strategy would greatly damage portfolio returns if the economic shock (and its effects) trigger the indicator over a longer period of time. As a long term portfolio strategy, the viability of generating strong and stable returns would greatly be reduced if the All Weather strategy would be used over a period of many months to 1+ years. As such when multiple indicators are incorporated into the investment strategy, there are some modifications that can be considered.

Localized Economic Shocks

If there was to be an economic shock where its effects were localized in a specific country, the portfolio could relocate across indexes that are not affected by localized shocks. For example, if the US were to experience an economic downturn, triggering an indicator, but the other country-specific indicators are not triggered, the portfolio could adopt one of the below strategies:

- The US position in the SPX and RMSG could be liquidated and allocated across LP01TRUE, NKY, and MXDK
- The US position in the SPX and RMSG could be liquidated and supplemented with the All Weather Portfolio



Appendix

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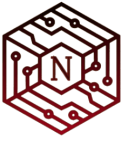
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Additional Visualizations