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Article in SSRN Electronic Journal · May 2020

DOI: 10.2139/ssrn.4649247

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The All-Weather Portfolio Approach: The holy grail of portfolio management

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First published: May 2020

Abstract

The research paper provides an analysis of the All-Weather portfolio approach's effectiveness in portfolio construction. It validates Bridgewater Associates' 2009 research by examining market data and replicating the investment strategy using ETF funds. The study identifies that traditional portfolios, which are typically heavily concentrated in equity securities, tend to incur higher risks for lower returns. The All-Weather strategy can be used as a case study to construct portfolios that can achieve attractive risk and return profiles. Different portfolio modelling techniques are implemented to test portfolio performance. There is potential for investors to optimise returns and manage risks more efficiently through strategic asset diversification, geographic allocation, and correlation analysis. The paper highlights the All-Weather approach's while addressing the limitations of this model.

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1 Introduction

The concept of the All-Weather Portfolio, pioneered by Bridgewater Associates, embodies a strategy of asset diversification designed to generate resilient returns across various market conditions. Characterized by its diversified asset composition, this portfolio paradigm seeks to transcend traditional portfolio management by offering a shield against diverse market fluctuations.

Historical analyses of institutional portfolios reveal a recurring theme of suboptimal asset diversification, with an estimated 75% to 80% of portfolio risk typically tethered to equity securities. Such a configuration exposes these portfolios to the full brunt of stock market volatilities, a phenomenon markedly evident in portfolios with an equity concentration as high as 90% [6]. 6 represents the cumulative performance of the different stock market during the period 1900 – 2019. The obvious observation is that if in this period the investor had decided to follow a geographically diversified approach by investing equally on his portfolio in the five selected countries, the investor would have realized a cumulative performance of the portfolio approaching the best result on this analysis the return of an investment on the US equity market [7].

The principles of Modern Portfolio Theory, as formulated by Harry Markowitz, underscore the virtues of diversification. Markowitz’s seminal work suggests that a well-diversified portfolio, characterized by maximum decorrelation among its constituents, can enhance performance. Neglecting such diversification could result in the forfeiture of substantial returns, measured in hundreds of basis points. The addition of geographic diversification further underscores this point. The 20th-century investment landscape offers poignant lessons, where countries like Russia and Germany faced systemic crises in the 1920s, leading to colossal investor losses. 7 represents the worst equity excess return drawdowns across countries Geographic diversification is an important vector of performance for the overall return of the portfolio, as evidenced by the results of previous centuries where investments concentrated on a single country, such as Russia in the early 1920s and Germany in the mid-1920s, both of which experienced systemic crises resulting in significant losses for investors and a total loss on a portfolio concentrated on a single country [2].

In contrast, a hypothetical portfolio evenly distributed across five selected countries during the same period would have yielded cumulative returns comparable to those of the robust U.S. equity market [7]. 8 represents the cumulative excess returns of an equally weighted geographically diversified portfolio of stocks and bond compared to a concentrated investment in the US and global set of countries. If we take the analysis a step further, the performance of a geographically diversified portfolio with an equal allocation has consistently outperformed over the last 70 years [7]. Extending this analysis reveals that for the past seven decades, a geographically diversified portfolio with equal allocation has consistently delivered superior performance [2].

This strategic allocation not only bolstered returns but also mitigated maximum potential losses, as reflected in the drawdown analysis of the portfolio’s components [7]. 9 represents the maximum drawdown of an equally weighted geographically diversified portfolio of stocks and bond compared to a concentrated investment in the US and global set of countries. This consistency in the result is done while minimizing the maximum losses of the portfolio, as evidenced by the drawdowns between the different components of the analysis [7].

The conventional wisdom advocating a 60/40 asset-to-bond allocation ratio is predominantly driven by the asset component's performance, which demonstrates a staggering 95% correlation with the portfolio's overall returns. This relationship challenges the common investor assumption that a 40% bond allocation constitutes effective diversification [6]. 10 represents the correlation analysis of the drawdowns of a 60/40 portfolio. X-axis represent the period analysed, while the y-axis represents the overall drawdown of the portfolio analysed (Bridgewater Associates, 2009).

It is essential to revisit the foundational principles of portfolio construction, particularly the risk/return profiles of various asset classes and their alignment with an investor's risk tolerance. The quest for an 8% return traditionally directs investors towards a heavy reliance on equities. However, the All-Weather approach introduces a nuanced strategy, suggesting that leveraging assets can optimize the risk/return ratio without compromising diversification [6]. 11 represents the risk-return of different asset classes. X-axes represent the expected risk of each asset, while the y-axis represents the overall expected total return of each asset in the graph (Bridgewater Associates, 2009).

It is important to stress the key to getting the best possible return is to differentiate between combinations of slightly correlated assets and combinations of highly correlated assets, since a low correlation, or even a negative correlation, is a driver of portfolio return. 12 represents the risk-return of different asset classes. X-axis represent the period analysed, while the y-axis represents the performance of each asset selected in the analysis [6]. In this sense, we can analyse the effect of the correlation on the risk incurred by the portfolio, where a correlation of 60% would imply a probability of loss of funds of 38% annually, for a risk/return ratio of 0.31, while a portfolio with a neutral correlation will have a much lower probability of loss (of the order of 11%) while having an improved risk/return ratio (of the order of 1.25, i.e. practically five times the return of the former).

The All-Weather Portfolio approach aims at incorporating different asset classes in its allocation while scrupulously respecting the increase and decrease matrix in inflation and growth conditions to naturally neutralize the losses of one asset with the gains of another asset class and all this without forgetting the geographical diversification factor which is integrated into the portfolio construction [6].

2 Modeling of the All Weather portfolio

2.1 Mathematical foundations

This part structures the mathematical foundations used in the modeling part of this paper. All formulas are extracted from [4].

2.1.1 Markowitz portfolio construction

The return on an asset is based on its return and its portfolio weighting. The portfolio return can be calculated using the following formula:

$$\sum_{i=1}^N w_i \cdot r_i$$

The portfolio return expression is then used to calculate two critical portfolio features for investors: expected performance as indicated by the average return and risk as indicated by the standard deviation of returns.

The standard deviation of the portfolio's returns is calculated using the following formula:

$$\sigma_P = \sqrt{\sum_{i=1}^N \sum_{j=1}^N w_i \cdot w_j \cdot \rho_{ij} \cdot \sigma_i \cdot \sigma_j}$$

where w_i is asset's weight i , w_j is the asset's weight j , ρ_{ij} is the asset's standard deviation, σ_i is the asset's standard deviation and ρ_{ij} is the correlation between the assets i, j .

Due to the computational burden associated with relying on many assets, we can employ the matrix form for easier implementation. Essentially, we multiply the weight vector by the variance-covariance matrix and the transpose of the weight vector:

$$\sigma_P = \sqrt{w \cdot \Sigma \cdot w'}$$

where w is the vector of weights, Σ is the matrix of variance-covariance and w' is the weight vector transposed.

2.1.2 GMV Portfolio construction

The GMV portfolio is only based on the covariance matrix estimation. This matrix estimator is inversed in the formula to determine the weights of the portfolio. The unbiased estimator of the inverse covariance matrix can be approached as:

$$\hat{\Sigma}_{\text{unbiased}} = \frac{1}{T - n - 2} \sum_{t=1}^T (r_t - \hat{\mu})(r_t - \hat{\mu})'$$

where $\hat{\mu} = \frac{1}{T} \sum_{t=1}^T r_t$ is an estimator for the mean returns, T the number of observations, n the number of assets and r_t the vector of financial returns for the n assets observed at time t .

2.1.3 PCA analysis

Mathematically we can approach it as:

$$\hat{\Sigma}_{\text{3factors}} = \Phi_f \Lambda_f \Phi_f' + \Sigma \epsilon$$

The variance of the residuals ϵ_i can be computed as (Clauss, 2011):

$$\text{Var}(\epsilon_i) = \text{Var}(r_i) - \phi_{i1}^2 \lambda_1 - \phi_{i2}^2 \lambda_2 - \phi_{i3}^2 \lambda_3 \quad (1)$$

with Λ_f representing the diagonal matrix of the first three eigenvalues of the unbiased estimator of the covariance matrix, Φ_f the matrix with the first three eigenvectors, and Σ_ϵ the diagonal residual covariance matrix determined for each asset i .

2.1.4 Black-Litterman approach

The weights in a Black-Litterman can be approached as:

$$\omega = \frac{1}{A} \tilde{\Sigma}^{-1} \tilde{\mu}$$

with $\tilde{\Sigma}$ the covariance matrix between assets returns of length $n \times n$, $\tilde{\mu}$ the vector of the expected excess returns equal to $\mu - r_f e$ with μ the expected returns, r_f the risk-free rate and e a vector of 1 of length n and finally.

The unbiased estimator for mu and covariance can be approached as follows:

$$\tilde{\mu} = \frac{1}{T} \sum_{t=1}^T (r_t - r_f)$$

with r_t is as the return of the asset at time t and r_f as the risk-free rate asset return at time t .

The unbiased covariance estimator can be approached similarly as the the Global Minimum Variance (GMV) case [4]:

$$\tilde{\Sigma} = \frac{1}{T - n - 2} \sum_{t=1}^T (r_t - \hat{\mu})(r_t - \hat{\mu})'$$

Black-Litterman approach is quantitative approach that integrate investor views in a relevant way. This method adds to economic predictions statistical uncertainty. It is based on a Bayesian approach [4].

The Black-Litterman returns are the following mixed estimates:

$$\hat{\mu}_{mixed} = \left(\tau \tilde{\Sigma}^{-1} + \Omega^{-1} \right)^{-1} \left[\tilde{\Sigma}^{-1} \tilde{\mu} + \Omega^{-1} Q \right]$$

with Q the economic views quantified by average returns, τ the confidence parameter in the views and Ω the matrix of uncertainty associated with the economic views; we assume that Ω is a diagonal matrix with diagonal elements equal to variances of assets returns.

2.2 Packages

The modeling is conducted in R program.

We import the necessary libraries to perform the first analysis.

- `library(tidyverse)`: The tidyverse package constitutes a collection of R packages meticulously designed to work seamlessly in unison for data manipulation, visualization, and analysis. It encompasses packages like `ggplot2` for data visualization, `dplyr` for data manipulation, `tidyr` for data tidying, and more. Loading tidyverse avails all these packages for utilization during your R session, streamlining your data analysis workflow.
- `library(quantmod)`: The quantmod package primarily caters to quantitative financial modeling and analysis. It furnishes an array of functions and tools for handling financial data, such as downloading and managing stock price data, conducting technical analysis, and modeling financial time series.
- `library(DataExplorer)`: The DataExplorer package serves the purpose of preliminary data exploration and analysis. It offers functions to generate summary statistics, visualize missing data, plot variable distributions, and more. It can aid in obtaining a quick overview of your data before delving into more extensive analyses.
- `library(corrplot)`: The corrplot package specializes in visualizing correlation matrices. It provides functions for generating visually appealing and informative correlation plots, which prove valuable for comprehending relationships between variables within your data.
- `library(scales)`: The scales package provides an assortment of scales and formatting functions tailored for R graphics. It is often employed in conjunction with other plotting packages, such as `ggplot2`, to customize the appearance of plots, including axes, labels, and color scales.

2.3 Investment universe

2.3.1 Fund selection

This investment universe is designed to provide diversified exposure across a range of asset classes, including broad market indices, emerging market equities, government bonds, commodities, and precious metals. This selection is intended to balance risk and return while capturing growth opportunities and providing a hedge against inflation.

- VTI (Vanguard Total Stock Market ETF): Broad exposure to the global stock market.
- EMGF (iShares MSCI Emerging Markets Multifactor ETF): Exposure to emerging markets with favorable exposure to value, quality, momentum, and size factors.
- IEF (iShares 7-10 Year Treasury Bond ETF): Exposure to intermediate-term government bonds.
- DBC (Invesco DB Commodity Index Tracking Fund): Exposure to a basket of commodities.
- GLD (SPDR Gold Trust): Exposure to gold.

2.3.2 Economic data

To connect our investment universe selection to the asset allocation, we can refer to market outlooks from prominent Wall Street's most reliable market commentaries. We take the economic data from Goldman Sachs Asset Management, BlackRock, and JPMorgan Asset Management. On average, the three financial institutions expect global GDP growth of +3.0% in 2023, US GDP growth of +2.0%, and S&P 500 earnings growth of +8%. They also expect the US 10-year Treasury yield to reach 3.3%. In terms of asset allocation, all three institutions are overweight on equities, with Goldman Sachs Asset Management being the most overweight. They are also underweight on bonds, with JPMorgan Asset Management being the most underweight.

Overall, the market outlooks from these three financial institutions suggest that equities are still the preferred asset class for 2023, despite the expected slowdown in economic growth. Investors should consider diversifying their portfolios with other asset classes, such as bonds and commodities, to reduce risk.

This investment universe is a good option for investors who are looking for a diversified portfolio that offers the potential for both growth and income. The assets in this universe are supported by economic data, market outlook, and investment considerations.

2.3.3 Rationale

We have carefully chosen a set of five trackers (ETFs) to represent our investment universe. An ETF can be defined as a financial product that is based on a basket of different assets, to replicate the actual performance of each selected investment. An ETF has more or less the same proportion of the underlying components of the basket, depending on the style of management of the asset manager. Below is the Exchange-Traded Funds (ETF) chosen as the investment universe:

- Equities (VTI): VTI provides broad exposure to the global stock market, which is expected to benefit from economic growth.
- Emerging market equities (EMGF): EMGF provides exposure to emerging markets with favorable exposure to value, quality, momentum, and size factors. Emerging markets have the potential for higher growth than developed markets, but they also come with more risk. EMGF mitigates some of the risk by investing in companies with favorable exposure to specific factors.
- Government bonds (IEF): IEF provides exposure to intermediate-term government bonds, which are typically considered to be low-risk investments. This can provide stability to a portfolio in times of economic uncertainty.
- Commodities (DBC): DBC provides exposure to a basket of commodities, which can be a good way to diversify a portfolio and hedge against inflation. However, it is important to note that commodities are volatile investments.
- Precious metals (GLD): GLD provides exposure to gold, which is a traditional safe haven asset that can provide protection against inflation and market volatility.

Overall, this investment universe is well-diversified and offers a mix of assets with different risk and return profiles. This makes it a good choice for investors with a variety of investment objectives and time horizons.

Our selection strategy is based on several fundamental considerations:

- Investment universe: The investment universe aims at representing different asset classes in order to construct a multi-asset portfolio.
- Diversification strategy: Our commitment to constructing a well-rounded portfolio has been affirmed through diversification across various sectors and industries. Such diversification is a critical risk management tool, curbing overexposure to a single sector or asset class.
- Historical data availability: The selected trackers benefit from a rich repository of historical data and extensive research. The accessibility of such data enable these ETFs to rigorous portfolio management analysis and comprehensive research.

2.4 Data cleaning and analysis

2.4.1 Data cleaning

We initiate data cleaning, a crucial step in data analysis:

- Extracting adjusted closing prices: We use the `lapply` function to obtain adjusted closing prices, commonly used for return calculations, for a list of stock tickers. This code iterates through each ticker and fetches the adjusted closing prices.
- Combining stock returns: To consolidate the adjusted closing prices, we employ `cbind`, creating a data frame where each column represents a specific stock's adjusted closing prices.
- Renaming columns: We label the columns with their corresponding stock tickers, facilitating easy identification.
- Handling missing data: We remove rows with missing values from the dataset for quality and consistency.

Arithmetic returns are used for performance assessment, offering a clear view of gains and losses, suitable for short-term analysis, and ensuring transparency.

2.4.2 Data analysis

Data ranges from 01/01/2019 to 31/08/2023, capturing the period before and after the Covid 19 pandemic. We plot the rebased performance of the trackers selected in our investment universe. From the graph below, we can clearly see the out performance of equity tracker (VTI) by a considerable margin with respected to the other asset classes. The equity market has outperformed all of the other asset classes mentioned above since 2019 for a number of reasons.

- Strong economic growth: The global economy has grown at a healthy pace since 2019, which has supported corporate earnings growth. This has made equities more attractive to investors.
- Low interest rates: Interest rates have been low since 2019, which has made equities more attractive relative to other asset classes, such as bonds.
- Government stimulus: Governments around the world have enacted a number of stimulus measures to support the economy during the COVID-19 pandemic. This has boosted consumer spending and investment, which has benefited equities.
- Corporate earnings growth: Corporate earnings have grown strongly since 2019, as companies have benefited from the strong economy and low interest rates. This has made equities more attractive to investors.

The equity market is the riskiest of the asset classes mentioned above because it is more volatile and subject to larger swings in price. However, it has also been the most rewarding asset class over the long term, as it has generated higher returns than other asset classes, such as bonds and commodities.

Here are some additional insights on the outperformance of the equity market:

- The equity market has benefited from a number of technological trends, such as the rise of e-commerce and cloud computing. These trends have led to the growth of new companies and industries, which has created new investment opportunities for investors.
- The equity market has also benefited from the globalization of the economy. Companies are now able to operate in multiple countries, which has helped them to grow their businesses and increase their profits.
- The equity market has become more accessible to individual investors in recent years. This has led to an increase in demand for equities, which has helped to drive up prices.

Overall, the equity market has outperformed all of the other asset classes mentioned above since 2019 due to a number of factors, including strong economic growth, low interest rates, government stimulus, corporate earnings growth, technological trends, globalization, and increased access for individual investors.

To enhance our data analysis, we can perform statistical analysis on the monthly returns of each stock. This helps us evaluate their performance and behavior during the observed time frame. Please note that the figures derived from this analysis are presented in monthly returns.

Using monthly data to smooth the data and transform it to a close approximation to the Gaussian distribution has several advantages [4]:

- Reduced noise: Monthly data is less noisy than daily or weekly data. This is because it averages out the short-term fluctuations in the data.

- Improved normality: Monthly data is more likely to be normally distributed than daily or weekly data. This is because the Central Limit Theorem states that the distribution of the sum of a large number of independent and identically distributed random variables will be approximately normal, even if the original distribution is not normal.
- Easier to model: Gaussian distributions are easier to model than other types of distributions. This is because there are a number of well-established statistical methods for modeling Gaussian distributions.

There are also some disadvantages to using monthly data to smooth the data and transform it to a close approximation to the Gaussian distribution:

- Loss of information: Monthly data is less informative than daily or weekly data. This is because it averages out some of the detail in the data.
- Time lag: Monthly data has a time lag. This means that it does not reflect the latest changes in the underlying data.

Overall, the utility of using monthly data to smooth the data and transform it to a close approximation to the Gaussian distribution depends on the specific application. In order to reduce noise and improve normality, then using monthly data is a good option. However, if the goal is to capture the latest changes in the data or to preserve all of the information in the data, then using more frequent data is a better option.

Correlation is a fundamental concept related to diversification, which seeks to use poorly correlated and non correlated assets to construct a portfolio. Diversification aims to boost returns while minimizing risk by investing in assets that respond differently to various events. Prudent investors seeking risk mitigation will diversify their portfolios.

In our investment universe, opportunities for diversification arise. Defensive assets like gold (TICKER: GLD) can effectively diversify when combined with more aggressive ones. For instance, the Vanguard Total Index tracker (TICKER: VTI) has a poor correlation with gold (TICKER: GLD). iShares 7-10 years Treasuries Index tracker (TICKER: IEF) exhibits negative correlation with respect to international and emerging market equities ¹.

2.5 Modelling of the portfolio

2.5.1 Unbiased Global Minimum Variance (GMV) portfolio

Modern Portfolio Theory (MPT) is founded on several market and investor assumptions. Several of these assumptions are stated explicitly, while others are implied. Markowitz's contributions to (MPT) in portfolio selection are based on the following basic assumptions [3]:

- Investors are rational (they seek to maximize returns while minimizing risk, or minimize risk while maximize return).

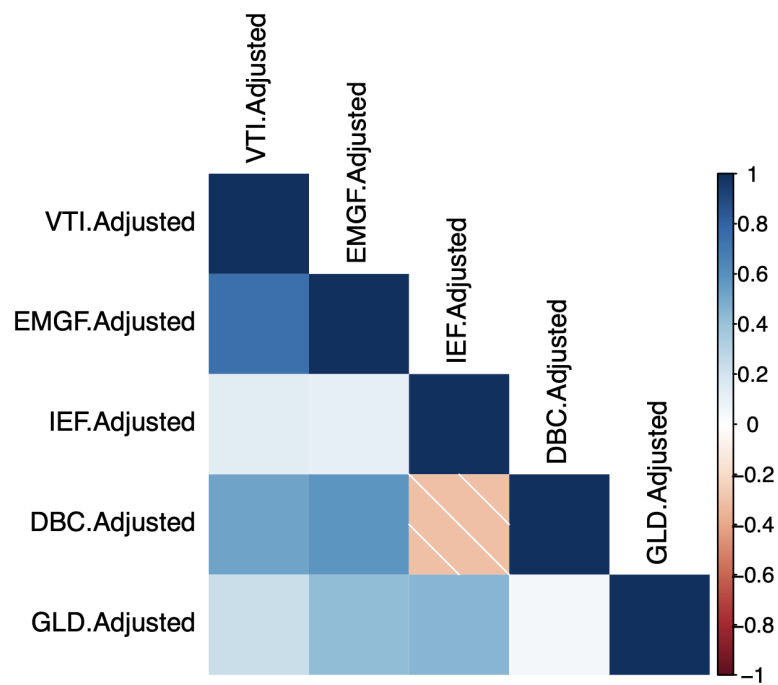


Figure 1: Correlation analysis of the funds returns.

- Investors will accept increased risk only if compensated with higher expected returns.
- Investors receive all relevant information regarding their investment decision.
- Investors can borrow or lend an unlimited amount of capital at a risk-free rate of interest.

In the context of time series data analysis, one of the crucial applications is the division of the data set into a training set and a testing set based on temporal order. This approach is particularly important when dealing with data that evolves over time, such as stock prices in this instance.

The training set typically comprises historical data, while the testing set contains more recent observations. This temporal separation allows for the evaluation of predictive models and forecasting techniques. By using historical data to train the model and then assessing its performance on more recent data, analysts can gauge the model's ability to make accurate predictions and anticipate future trends. Time series data applications are essential in fields like finance, where understanding and forecasting trends over time is important

For the purpose of modelling, we will shrink the data set into two different sub-samples. We can define the following parameters:

- The first sub-sample will cover the first 20 trading month covered in the data set.
- The second sub-sample will cover the rest of the data set, covering the equivalent of 36 trading month.

We can see in this instance that the portfolio is mixed, with some long and short positions. The capital is fully invested, with some important exposure in the long part of the portfolio like the bond fund 2.



Figure 2: GMV portfolio weight. Each bar represents a fund weight from left to right: VTI, EMGF, IEF, DBC, GLD.

2.5.2 Implementation of Principal Component Analysis (PCA)

Principal Component Analysis (PCA) is a technique used to analyze and reduce the dimensionality of a dataset while retaining as much variance as possible [4]. We perform the PCA analysis using the second subsample starting from the trading month number 20 of the sample to the trading month number 56.

Principal component analysis (PCA) is an unsupervised machine learning technique that can be used to identify the underlying patterns in a dataset. PCA works by transforming the dataset into a new set of variables, called principal components, that are uncorrelated with each other. The principal components are ordered in terms of how much variance they explain in the dataset, with the first principal component explaining the most variance and the last principal component explaining the least variance.

PCA can be used for a variety of tasks, including dimensionality reduction, data visualization, and feature extraction. In the context of portfolio management, PCA can be used to [4]:

- Identify the underlying factors that drive the returns of the stocks in the portfolio.
- Construct more diversified portfolios by selecting stocks with low correlations with each other.
- Reduce the dimensionality of the portfolio by selecting the most important principal components.

The PCA results can be interpreted as follows:

- The first principal component can be thought of as a market factor. This factor represents the overall movement of the stock market. In other terms, the first factor explains half of the variance of the portfolio overall and can be assimilated as a proxy to the sensitivity to market fluctuations.



Figure 3: PCA portfolio weight. Each bar represent a fund weight (left to right): VTI, EMGF, IEF, DBC, GLD.

- The second and third principal components can be thought of as style factors. These factors represent the different styles of investing, such as value investing and growth investing. From the type of stocks retained, we have shortlisted an important number of growth stocks in the technology sector, which could explain part of the overall variance of the portfolio.
- The remaining principal components can be thought of as idiosyncratic factors. These factors are specific to the individual stocks in the portfolio.

3 represents the portfolio allocation using the PCA method.

2.5.3 Implementing the Tangency Portfolio (TP)

In time series data analysis, a crucial application involves splitting the dataset into training and testing sets based on temporal order. This is vital when working with data that evolves over time, such as stock prices or weather observations.

The training set consists of historical data, while the testing set contains more recent observations. This division allows analysts to assess predictive models and forecasting techniques. By training the model on historical data and evaluating it with recent data, we can determine its ability to make accurate predictions. This is especially important in finance for understanding and forecasting trends over time.

For modeling purposes, we'll create two sub-samples with defined parameters.

- The first sub-sample will cover the first 20 trading month covered in the data set.
- The second sub-sample will cover the rest of the data set, covering the equivalent of 36 trading months.

The portfolio allocation consists of both long positions, where investors expect favorable returns, and short positions, where they anticipate weaker performance. Here's a more detailed explanation

of each asset class allocation.

The long segment of the portfolio is allocated to assets where positive performance is expected.

- International Equities (Ticker: VTI, Allocation: 17.54%): This segment of the portfolio is dedicated to international equities, with VTI making up 17.54% of the overall portfolio. Investors are optimistic about the performance of international equities, which is why they have allocated a significant portion of their capital to this asset class.
- US Short-Term Maturity Bond (Ticker: IEF, Allocation: 88.91%): The largest allocation in the long positions is in US short-term maturity bonds, represented by IEF. This allocation indicates a strong conviction in the stability and income potential of short-term bonds.
- Emerging Markets (Ticker: EMGF, Allocation: 5.7%): In the case of emerging markets, the allocation is bullish at 5.7%. This indicates that investors are taking a positive stance on the performance of emerging market assets, expecting their values to rise.
- Commodities (Ticker: DBC, Allocation: 0.06%): The allocation to commodities, represented by DBC, is even more conservative at 0.06%. This suggests a neutral outlook on commodities, which reflects a cautious approach towards commodities in the portfolio.

The short segment of the portfolio is allocated to assets where weak performance is expected.

- Gold (Ticker: GLD, Allocation: -12.83%): Gold is often considered a safe-haven asset, and this allocation suggests that investors still see value in holding gold as a hedge or store of value, albeit at a slightly reduced allocation.

In summary, the portfolio is strategically balanced between long positions, where investors have confidence in the assets' growth potential, and short positions, where they are expecting weaker performance. The specific allocations provide insights into the level of conviction and sentiment regarding each asset class 4.

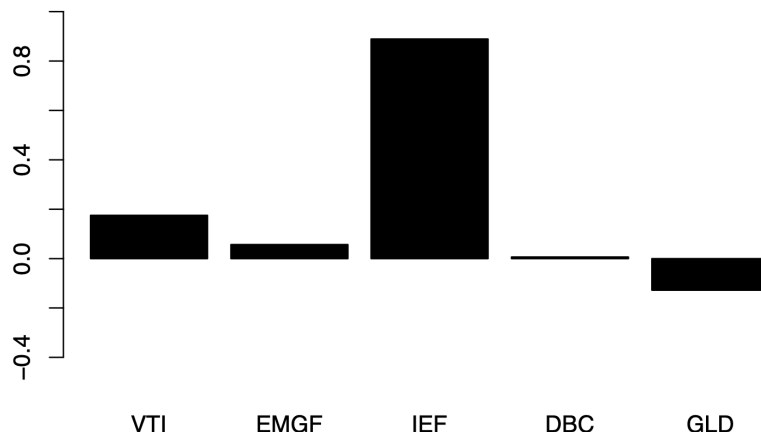


Figure 4: GMV portfolio weight. Each bar represent a fund weight (left to right): VTI, EMGF, IEF, DBC, GLD.

2.5.4 Implementing Black-Litterman Approach

In order to construct our views matrix, we can base our assumptions on the economic outlooks provided from a group of asset managers to confront outlooks and assess their perspective on markets. We will delve deeper into the outlooks from BlackRock [5], Goldman Sachs Asset Management (GSAM) [8], and J.P. Morgan Asset Management (JPMAM) [9] on gold, international equities, commodities, short-term US Treasuries, and emerging markets

International equity markets

International equity markets have underperformed US equity markets since 2019. However, they have started to outperform in 2023, as valuations have become more attractive and corporate earnings growth has picked up.

- BlackRock: BlackRock is neutral on international equities. The firm believes that international equities are undervalued, but it is cautious due to the risks associated with investing in international markets, such as currency fluctuations and political instability.
- Goldman Sachs Asset Management (GSAM): GSAM is neutral on international equities. The firm believes that international equities are undervalued, but it is cautious due to the risks associated with investing in international markets, such as currency fluctuations and political instability.
- J.P. Morgan Asset Management (JPMAM): JPMAM is overweight international equities. The firm believes that international equities are undervalued and that corporate earnings growth will pick up in the coming months.

Emerging market equity

Emerging market equity has underperformed US equity since 2019. However, it has started to outperform in 2023, as valuations have become more attractive and corporate earnings growth has picked up.

- **BlackRock:** BlackRock is neutral on emerging market equities. The firm believes that emerging market equities are undervalued, but it is cautious due to the risks associated with investing in emerging Currency fluctuations and political instability are examples of market risks.
- **GSAM:** GSAM is underweight emerging market equities. The firm believes that emerging markets are more risky than developed markets due to their higher exposure to China and other emerging economies.
- **JPMAM:** JPMAM is underweight emerging market equities. The firm believes that emerging markets are more risky than developed markets due to their higher exposure to China and other emerging economies.

US short-term treasuries

US short-term treasuries have underperformed most other asset classes since 2019. This is due to the fact that interest rates have been rising during this period.

- **BlackRock:** BlackRock is overweight short-term US Treasuries. The firm believes that the outlook for short-term US Treasuries is positive, as the Federal Reserve is expected to continue raising interest rates to combat inflation.
- **GSAM:** GSAM is overweight short-term US Treasuries. The firm believes that the outlook for short-term US Treasuries is positive, as the Federal Reserve is expected to continue raising interest rates to combat inflation.
- **JPMAM:** JPMAM is neutral on short-term US Treasury bonds. The firm believes that the outlook for short-term US Treasury bonds is neutral, as the Federal Reserve is expected to continue raising interest rates, but yields are already relatively high.

Commodities

Commodities have outperformed most other asset classes since 2019. This is due to a number of factors, including strong demand from China and the ongoing war in Ukraine.

- **BlackRock:** BlackRock is overweight commodities. The firm believes that commodity prices will remain supported by strong demand from China and the ongoing war in Ukraine.
- **GSAM:** GSAM is overweight commodities. The firm believes that commodity prices will remain supported by strong demand from China and the ongoing war in Ukraine.
- **JPMAM:** JPMAM is overweight commodities. The firm believes that commodity prices will remain supported by strong demand from China and the ongoing war in Ukraine.

Gold

Gold has outperformed most other asset classes since 2019. This is due to a number of factors, including concerns about global economic growth, geopolitical tensions, and inflation.

- BlackRock: BlackRock is overweight gold in its portfolios. The firm believes that gold is a good hedge against inflation and geopolitical risk.
- GSAM: GSAM is overweight gold in its portfolios. The firm believes that gold is a good hedge against inflation and geopolitical risk.
- JPMAM: JPMAM is overweight gold in its portfolios. The firm believes that gold is a good hedge against inflation and geopolitical risk.

Overall, there is a general convergence of outlooks on gold, commodities, and short-term US Treasuries. All three asset managers are overweight these asset classes. However, there is some divergence of outlooks on international equities and emerging markets. BlackRock and GSAM are neutral on international equities, while JPMAM is overweight. GSAM and JPMAM are underweight on emerging markets, while BlackRock is neutral.

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Asset class	BlackRock	GSAM	JPMAM
Gold	Overweight	Overweight	Overweight
International equities	Neutral	Neutral	Overweight
Commodities	Overweight	Overweight	Overweight
Short-term US Treasuries	Overweight	Overweight	Neutral
Emerging markets	Neutral	Underweight	Underweight

Table 1: Investment outlook from various firms. Data from BlackRock, Goldman Sachs Asset Management (GSAM), and J.P. Morgan Asset Management (JPMAM), 2023.

In the Black-Litterman model, the expected returns of individual assets are represented by the Q vector. The Q vector is defined by the investor, and it reflects their views on the future performance of each asset. In the code provided, the investor has specified strong overweight positions in international equities (VTI) and US short-term maturity bonds (IEF), a relatively overweight position in emerging markets (EMGF), and neutral and underweight positions in commodities (DBC) and gold (GLD), respectively.

Once the Q vector has been defined, the Black-Litterman model can be used to calculate the optimal portfolio weights. The optimal portfolio weights are the weights that will maximize the expected return of the portfolio, subject to the investor's risk constraints.

In summary, the Black-Litterman code you provided defines the expected returns of individual assets and uses this information to calculate the optimal portfolio weights.

In summary, the following table combines views suggesting the following outlook scenario for each asset class with an expected Q value in percentages.

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The Black-Litterman optimization approach is a widely-used method for improving the estimation of expected returns and making asset allocation decisions. It addresses the limitations of traditional mean-variance optimization by incorporating investor views and market equilibrium considerations [4].

Asset Class	Ticker	Position	Percentage
International Equities	VTI	Strongly overweight	5
Emerging Markets	EMGF	Relatively overweight	1
US Short Term Maturity Bond	IEF	Strongly overweight	5
Commodities	DBC	Neutral	0
Gold	GLD	Relatively underweight	-2

Table 2: Outlook scenario for each asset class with expected Q value in percentages.

- Mixed estimation of returns: The code starts by computing expected returns using mixed estimation. This approach allows investors to incorporate their subjective views on assets into the asset allocation process while considering the overall market dynamics.
- Tactical allocation with views directly: This part of the code calculates the tactical asset allocation weights based on views directly. These weights reflect the investor's views on specific assets and are adjusted according to their confidence in those views.
- Tactical allocation with mixed estimation: Similarly, this part calculates tactical asset allocation weights, but this time, it uses the mixed estimation approach. This allows investors to take a balanced approach, combining both market equilibrium considerations and their own views in the asset allocation process.

Black-Litterman [1] offers a flexible framework for investors to incorporate their insights and views while maintaining a connection to market equilibrium. It's a valuable tool for optimizing portfolio allocation decisions, especially when investors have specific expectations or insights about the market.

We can add the following comments on the new portfolio allocation under Black-Litterman approach, including asset views.

- International Equities (Ticker: VTI, Allocation: 18.4%): The allocation to international equities is 18.4%. This allocation represents an "overweight" position compared to the neutral stance of the BlackRock outlook, indicating a high level of confidence in the favorable performance of international equities. However, it's essential to note that there are differing views among asset managers. BlackRock and GSAM are neutral on international equities, neither optimistic nor pessimistic about their outlook, whereas JPMAM is "overweight," indicating a bullish perspective. This divergence in views reflects the varying assessments of international equity performance.
- Emerging Markets (Ticker: EMGF, Allocation: 5.9%): The allocation to emerging markets is 5.9%, indicating a "relatively overweight" position. This aligns poorly with the views formulated by or benchmark asset managers. BlackRock outlook takes a neutral stance on emerging markets. JPMAM shares this neutral view, while GSAM adopts a more cautious stance by being "underweight," indicating a bearish outlook. The divergence in views highlights the risk-return trade-off associated with emerging markets.
- US Short Term Maturity Bond (Ticker: IEF, Allocation: 92.4%): The allocation to US short-term maturity bonds is 92.4%, reflecting a "strongly overweight" position. This significant overweight allocation aligns with the views of both BlackRock and GSAM, which are bullish on short-term US Treasuries. In contrast, JPMAM maintains a "neutral" position, neither optimistic nor pessimistic. Short-term US Treasuries are seen as a favorable option for capital preservation and income generation, given the expected rise in yields.
- Commodities (Ticker: DBC, Allocation: 1.9%): The allocation to commodities is 1.9%, indicating a "neutral" position. This allocation is not consistent with the outlook of all three asset managers, which

are "overweight" commodities. While commodity prices have exhibited volatility, they are expected to remain supported by strong demand from China and geopolitical tensions. Nevertheless, we take into account the downside potential in our assessment, reducing our exposure to commodities overall. We take into account the cyclical nature of commodity prices, which may not experience continuous growth.

- Gold (Ticker: GLD, Allocation: -18.22%): The allocation to gold is -18.22%, reflecting an "underweight" position. This is contrarian to the views of all three asset managers, who are collectively "overweight" on gold. This indicates a shared belief that gold is a sound investment at this time, particularly as it is considered a safe-haven asset sought after during periods of economic uncertainty. However, we believe, investor won't be compensated enough for holding gold in a diversified portfolio.

We can add comments on the weightings with respect to the benchmark views:

- The portfolio's strong overweight position in international equities represents a bullish stance, despite differing views among asset managers. BlackRock and GSAM maintain a neutral position, while JPMAM's overweight perspective suggests a higher degree of confidence in the outlook for international equities.
- The relatively overweight position in emerging markets aligns with the cautious approach recommended by BlackRock. Differing views from GSAM and JPMAM indicate varying risk appetites, acknowledging the challenges associated with investing in these markets.
- The significant overweight allocation to US short-term maturity bonds is a key feature of the portfolio allocation. This reflects confidence in the short-term Treasuries and is supported by BlackRock and GSAM's bullish stance, with JPMAM taking a neutral position.
- The relatively neutral allocation to commodities is consistent with the cyclical nature of these assets. The portfolio takes a more conservative stance, despite expectations of continued strength in commodity prices.
- The relatively underweight position in gold underscores the risk of the associated asset class in the short term. Our weighting shows a contrarian view on this particular asset class compared to all three asset managers.

Overall, the portfolio allocation under the Black-Litterman approach takes into account a broader spectrum of views from different asset managers and integrates them into a more specific allocation that reflects varying degrees of optimism and caution across different asset classes [1]. Incorporating views into the portfolio has resulted in diverse adjustments across asset classes, reflecting the investor's evolving outlook on each. These changes are indicative of a dynamic strategy that aims to capitalize on various market scenarios. It's crucial to consider these allocations within the context of the investor's overall investment objectives and risk tolerance, as they play a pivotal role in shaping the portfolio's risk-return profile.

Our updated asset class allocations are generally consistent with the economic views of the asset managers we have cited, with some exceptions.

- International Equities: We have increased our allocation to international equities from 17.54% to 18.4%. This remains overweight relative to the neutral stance of BlackRock and GSAM, but it is now more in line with the overweight stance of JPMAM.
- Emerging Markets: We have also increased our allocation to emerging markets from 5.7% to 5.9%. This remains a relatively overweight position, given that BlackRock and JPMAM are neutral on emerging markets, while GSAM is underweight. However, we have carefully considered the risks associated with emerging markets, such as currency fluctuations and political instability, and have

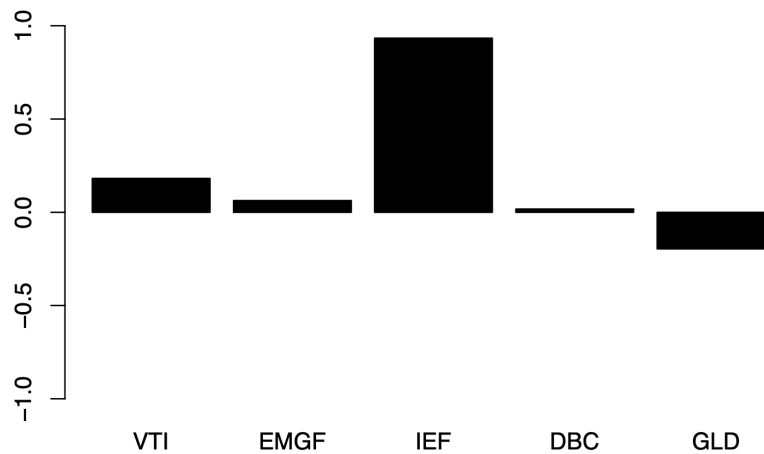


Figure 5: BL portfolio weight. Each bar represent a fund weight (left to right): VTI, EMGF, IEF, DBC, GLD.

determined that this level of overweight exposure is appropriate for our risk tolerance and investment goals.

- US Short-Term Treasuries: We have significantly increased our allocation to US short-term treasuries from 88.91% to 92.4%. This is now a strongly overweight position, consistent with the bullish views of BlackRock and GSAM. We believe that US short-term treasuries offer attractive yields and are a good way to preserve capital in the current uncertain economic environment.
- Commodities: We have increased our allocation to commodities from 0.06% to 1.9%. This is now a neutral position, but it is still below the overweight positions of all three asset managers. We have taken into account the cyclical nature of commodity prices and the potential for downside risk, and have determined that this level of exposure is appropriate for our overall portfolio.
- Gold: We have significantly reduced our allocation to gold from -12.83% to -18.22%. This is now a strongly underweight position, contrary to the overweight positions of all three asset managers. We believe that gold's safe-haven status is overvalued and that it is not a good investment for our portfolio at this time.

Our updated asset class allocations are more overweight international equities, emerging markets, and US short-term treasuries than the consensus view. We are also more underweight commodities and gold than the consensus view 5.

3 Limits and conclusion

3.1 Limits

As with any investment strategy, the All-Weather approach has potential limitations and underlying assumptions that must be acknowledged.

The sensitivity to changes in market conditions is a factor that can affect returns. The All-Weather approach implies that historical relationships between asset classes will persist in the future. However, market conditions may shift, resulting in alterations to correlations and performance dynamics. The relationships between asset classes can be disrupted by economic factors such as interest rate fluctuations, policy shifts, geopolitical events, and unanticipated disruptions. Investors should be aware that the All-Weather portfolio's historical performance may not be repeated under different market conditions.

The influence of transaction fees has also to be taken into consideration. Frequently, the All-Weather approach requires periodic rebalancing and reallocation of assets to maintain the desired asset allocation. There may be costs associated with these transactions, including brokerage fees, bid-ask spreads, and taxes. High transaction costs can diminish the portfolio's overall returns and impact its performance over time. It is crucial for investors to evaluate the impact of transaction costs in relation to the anticipated benefits of portfolio rebalancing.

Even though historical analysis and backtesting can provide valuable insights, it is essential to remember that past performance is not a guarantee of future results. In all market conditions, the All-Weather approach may not consistently outperform other strategies or benchmarks. Different economic cycles and market conditions may favor different investment approaches or asset allocations. Before implementing any investment strategy, including the All-Weather approach, investors should exercise extreme caution and undertake exhaustive research. Assumptions regarding the model and data can affect the overall profitability of the strategy. The All-Weather approach relies on numerous assumptions regarding asset class returns, volatilities, correlations, and risk measures. Typically, these assumptions are founded on historical information and statistical analysis. Nonetheless, data limitations, model selection, and estimation errors may affect the veracity of these assumptions. It is crucial to recognize that the effectiveness of the All-Weather approach is contingent on the quality and reliability of the underlying data and the robustness of the applied models.

Behavioral and psychological considerations can also influence the returns of the strategy. The All-Weather approach presupposes rational decision-making and strict adherence to the predetermined asset allocation. During times of market duress, investors may experience behavioral biases, emotional reactions to market volatility, or the temptation to deviate from the planned strategy. These psychological factors may have an impact on the efficacy of the All-Weather approach and its capacity to attain the intended risk-return objectives.

For investors interested in the All-Weather approach, addressing these limitations and assumptions is crucial. Understanding the potential drawbacks and undertaking ongoing monitoring and adjustments can help mitigate risks and improve the long-term efficacy of the strategy.

3.2 Conclusion

The All-Weather approach emphasizes diversification across asset classes with varying risk and return characteristics. Investors can implement this principle by constructing a diversified portfolio of stocks, bonds, commodities, and possibly additional asset classes. Careful consideration should be given to the selection of assets that have historically demonstrated minimal correlations, as this can enhance the portfolio's resilience during varying market conditions. The All-Weather approach is intended to perform reasonably well in a variety of market environments. Understanding that short-term fluctuations and volatility are a part of the investment voyage, investors should adopt a patient and disciplined mindset. It is essential to adhere to the selected asset allocation and avoid rash decisions based on short-term market fluctuations. When employing the All-Weather approach, it is crucial to conduct routine portfolio monitoring and rebalancing. Over time, market fluctuations can lead to asset allocation deviations. Periodic rebalancing is required to restore the original allocation percentages and preserve the portfolio's risk-return profile. Depending on individual preferences and circumstances, rebalancing may be performed annually, semiannually, or based on specific thresholds.

While the All-Weather approach provides a framework for portfolio management, it is essential to consider individual risk tolerance, financial objectives, and investment horizon. Investors may need to tailor their asset allocation to their circumstances. For instance, investors with a lower risk tolerance and a longer investment horizon may prefer a higher allocation to fixed income, while those with a higher risk tolerance and a longer investment horizon may prefer a higher allocation to equities. As market conditions evolve, it is essential to assess the All-Weather approach's continued suitability. The performance of asset classes may be impacted by economic trends, geopolitical events, and changes in monetary policies, so investors should remain informed of these factors. Regular evaluation of the All-Weather strategy's fundamental assumptions and performance drivers will ensure its continued relevance and efficacy.

Investors should carefully evaluate the impact of transaction costs, such as brokerage fees and bid-ask spreads, on the application of the All-Weather approach. In addition, tax implications, such as capital gains taxes, should be considered when rebalancing the portfolio. The advice of a financial advisor or tax expert can be invaluable for minimizing costs and maximizing tax efficiency. For investors to successfully implement the All-Weather approach, they must understand its underlying principles and rationale. Educating oneself on asset classes, risk management, and investment concepts can increase one's self-assurance and enhance decision-making. In addition, being cognizant of behavioral biases and maintaining discipline during periods of market volatility will enable investors to adhere to the chosen strategy and avoid emotionally motivated actions.

By considering these practical implications and implementing the All-Weather approach with care, investors can create robust, well-diversified portfolios designed to withstand a variety of market conditions and achieve their long-term investment goals. The key to the successful application of this approach is based on a regular monitoring, customization based on individual requirements, and a commitment to sound investment principles.

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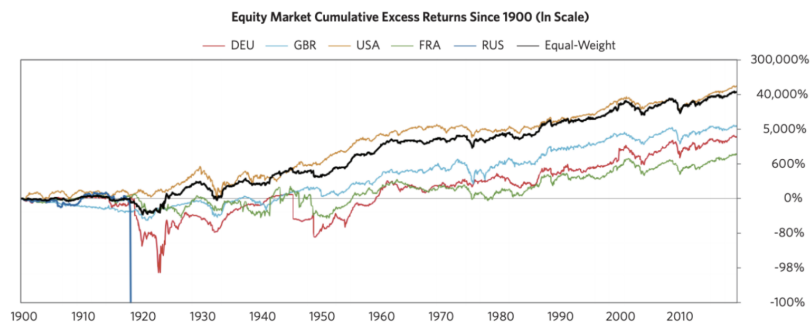


Figure 6: Appendix. Cumulative performance above of the stock market, 1900-2019.

Worst Equity Excess Return Drawdowns Across Countries (USD Terms)

Country	Data Starts	Period of Worst Drawdown	What Caused It To Happen	Years To Recover From Start of DD	Magnitude of Losses	Equal-Weight Returns During Country DD
Switzerland	Jan 1966	2007 - 2009	Global Financial Crisis	7	-51%	-49%
Equal-Weight	Jan 1900	1929 - 1932	Great Depression	13	-66%	--
Australia	Jun 1933	1969 - 1974	70s Inflation	10	-66%	-17%
UK	Jan 1900	1972 - 1974	70s Inflation	11	-72%	-20%
Norway	Feb 1970	1974 - 1978	70s Inflation	16	-74%	-17%
Japan	May 1949	1989 - 2003	Deflationary Grind	29 & Counting	-75%	-16%
Brazil	Aug 1994	1994 - 1998	Balance of Payments Crisis	24 & Counting	-77%	23%
Canada	Jan 1919	1929 - 1932	Great Depression	16	-79%	-65%
New Zealand	Dec 1984	1986 - 1990	Currency & Constitutional Crisis	32 & Counting	-81%	-10%
Sweden	Dec 1915	1917 - 1932	WWI and Great Depression	29	-81%	-30%
Spain	Dec 1915	1973 - 1982	Political Turmoil/70s Inflation	26	-83%	-19%
France	Jan 1900	1944 - 1950	WWII	15	-83%	41%
Taiwan	Jan 1988	1990 - 2001	Asian Financial Crisis	29 & Counting	-85%	0%
United States	Jan 1900	1929 - 1932	Great Depression	16	-85%	-64%
Italy	Jan 1948	1960 - 1977	Political Turmoil ("Years of Lead")	59 & Counting	-87%	49%
Korea	Jan 1965	1989 - 1998	Asian Financial Crisis	30 & Counting	-91%	33%
Germany	Jan 1900	1912 - 1923	WWI	47	-99%	-62%
Russia	Jan 1900	1912 - 1918	WWI and Bolshevik Revolution	Never	-100%	-31%

Figure 7: Appendix. Worst equity excess return drawdowns across countries.

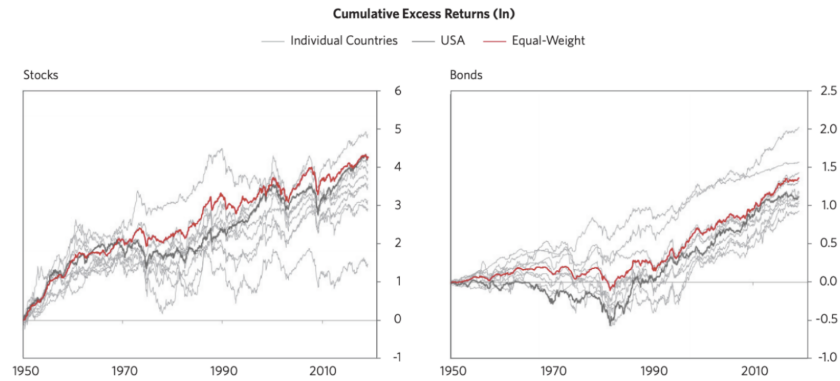


Figure 8: Appendix. Cumulative excess returns of an equally weighted geographically diversified portfolio.

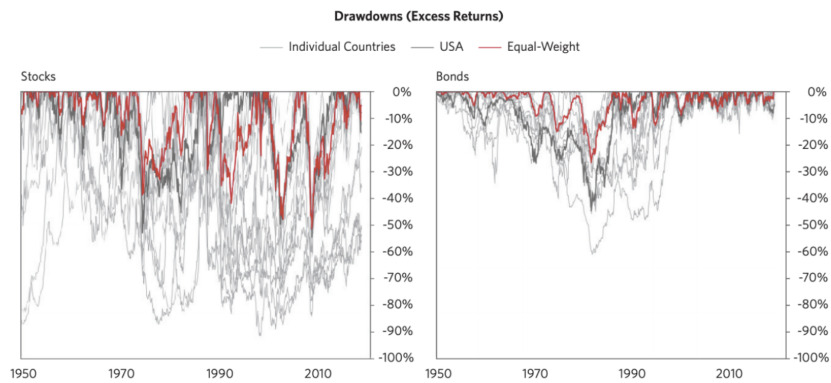


Figure 9: Appendix. Maximum drawdown of an equally weighted geographically diversified portfolio.

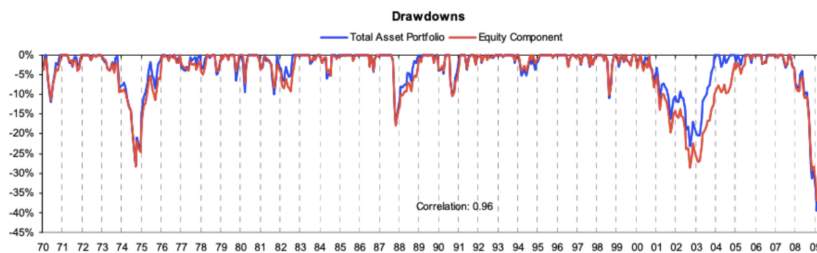


Figure 10: Appendix. Correlation analysis of the drawdowns of a 60% equity – 40% bond portfolio.

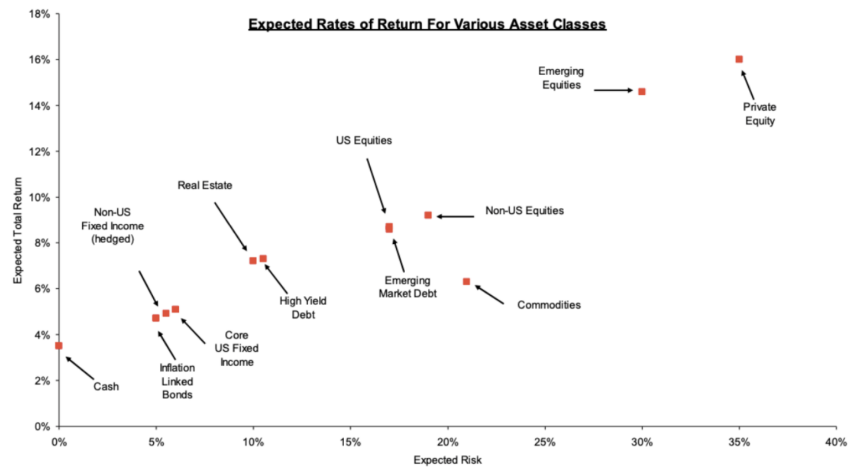


Figure 11: Appendix. Risk-return of different asset classes.

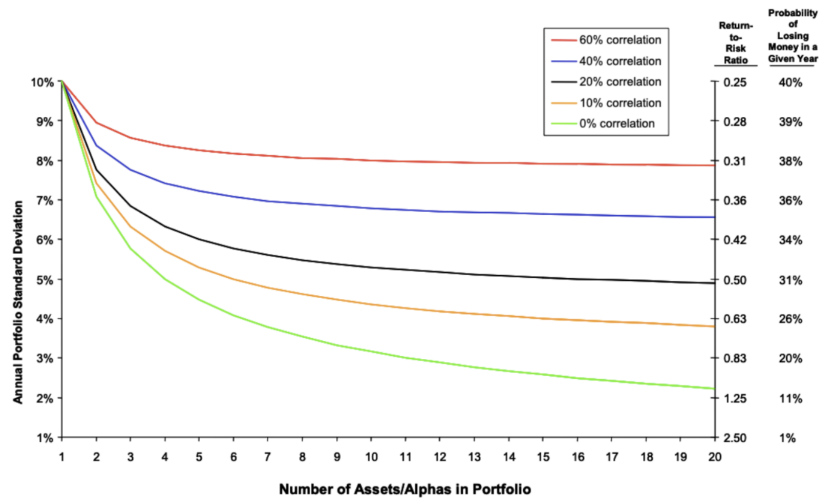


Figure 12: Appendix. Degree of correlation between assets and the impact on portfolio overall risk.