FACULTY OF ECONOMICS

COURSE: PROGRAMMING IN FINANCE AND ECONOMICS I

ACADEMIC YEAR: 2024-2025

TEACHER: PETER H. GRUBER

STUDENTS: LEONARDO ZOCCOLILLO, DAVIDE POMA, FEDERICA FILOGRASSO

# PROJECT 15, ADVANCED PORTFOLIO MANAGEMENT: COUNTRY OR SECTOR DIVERSIFICATION

SUMMARY:

**Advanced Portfolio Management: Country or Sector Diversification**

The project investigates the effectiveness of portfolio diversification using sectoral (industry-specific) indices and geographical (country-based) indices. The goal is to determine which diversification strategy yields better risk-adjusted returns.

## 1. How to Run the Program

The provided code, implemented in Python (Country.ipynb and Sector.ipynb), conducts the analysis for portfolio diversification. While both files perform identical procedures, they focus on distinct sets of ETFs.

These analyses are designed to function independently, with the separation of the files aimed at enhancing clarity and enabling direct comparison between the two datasets.

Follow these steps to run the program:

### 1.1 **Set-Up**

- Install the required Python libraries. It is a necessary step if the user has never used the library before.
- Ensure the following packages are imported and updated to the latest version:
    - pandas
    - numpy
    - matplotlib.pyplot
    - yfinance
    - scipy.optimize

Specifically, pandas was employed for handling data structures and time series, including tasks such as concatenating ETF returns and creating Data Frames. NumPy was mostly used for numerical computations and array handling. The minimize function from scipy.optimize was utilized to solve the optimization problem related to the creation of the tangency portfolio. Lastly, matplotlib.pyplot was used for graph generation, with the cm module employed to enhance visualization.

Running the code from top to bottom ensures that the required packages are installed and loaded correctly, allowing the code to execute properly.

Ensure that all packages are updated to their most recent versions.

Specifically, the yfinance package should be upgraded using the command *"!pip install --upgrade yfinance*".

### 1.2 **Data Requirements**:

For this study, two sets of ETFs that track the performance of indices have been selected.

The first group consists of ETFs tracking indices diversified by country, where all companies within each ETF originate from the same country.

The second group includes ETFs tracking indices diversified by sector, where all companies within each ETF belong to specific industries.

The same analysis was conducted on both types of diversified portfolios and, subsequently, the Sharpe ratios and cumulative returns were compared over the observation period to evaluate which portfolio demonstrated superior performance.

ETFs were chosen over the corresponding raw indices due to their better data accessibility and the fact that ETFs are denominated in U.S. dollars, whereas the majority of indices, particularly within the country dataset, are denominated in local currencies.

Additionally, the tracking error associated with ETFs is minimal and deemed acceptable.

It should be noted that throughout this report, the terms "ETFs" and "indices" are used interchangeably.

- The code fetches data via Yahoo Finance API (yfinance):
    - **Sector Indices**: Includes 18 sector indices (e.g., US energy, US materials).
    - **Country Indices**: Includes 18 global indices (e.g., S&P 500, DAX, Nikkei 225).

  These assets were carefully selected to minimize correlation that could potentially influence the results. Specifically, the country-based ETFs represent nations from different continents, avoiding countries exhibiting similar economic profiles. Similarly, for the sector-based ETFs, sectors that exhibit clear distinctions from one another were selected.

  Additionally, all companies within these indices are US based in order to avoid introducing an additional diversification factor that could affect variability.

- Ensure data availability for daily return data over a 10-year period.

  The analysis covers the period from 01 January 2014 to 31 December 2023. This ten-year timeframe was chosen as complete data for 2024 was not yet available.

  However, the time interval can be adjusted by modifying the "start" and "end" values and the “parameters” variables, allowing the calculation of returns for both the risk-free rate and the ETFs from different periods.

  For more comprehensive analyses, extending the time interval to include additional years is recommended.

- No explicit keys are needed for yfinance, but the most recent version is required.

  The data was imported using the Yahoo Finance API, which was selected for its accessibility and ease of use. Unlike many other APIs, it allows data retrieval without requiring a provider key, enabling users to execute the code without the need for additional permissions.

  This feature enhances the code's usability and accessibility for a broader audience.

1.3 **Running the Code**:

- Open the IPYNB files within a suitable Python environment, such as Jupyter Lab, Spyder, or other compatible notebook interfaces. Additionally, executing the code using Google Colaboratory represents a viable alternative.
- Execute the code.

1.4 **Output**:

- The program generates visualizations (e.g., time series of annual returns, Sharpe ratios, portfolio weights) and metrics summarizing the results.

## 2. Economic Problem and Goals

### 2.1 Problem Description

In this specific problem, investors aim to optimize portfolio performance choosing between a diversification:

1. **Across Industry Sectors**: Investments spread across different sectors (e.g., US energy, US healthcare) to reduce industry-specific risks. Only US Sectors have been used, in order to ensure consistency.
2. **Across Countries**: Investments are spread across countries (e.g., US, Germany, Japan) to mitigate risks tied to specific economies and currencies.

The objective is to compare sectoral and geographical diversification strategies by analysing risk-adjusted returns and portfolio stability, then comparing the Sharpe ratios and the cumulative returns of the tangency portfolio.

Markowitz's theory defines the principles of diversification and the relationship between risk and return, demonstrating that an investor could construct an efficient portfolio that minimizes risk for a given level of expected return by combining assets with correlations ranging [-1, 1).

The tangency portfolio represents the optimal mix of risky assets that maximizes an investor's risk-adjusted return. It lies at the intersection of the efficient frontier, which depicts the set of portfolios providing the highest expected return for a given level of risk, and the capital market line (CML), which extends from the risk-free rate to the efficient frontier. This point of tangency denotes the highest achievable Sharpe ratio, and it is constructed by combining assets such that no other portfolio of risky assets can achieve a higher return per unit of risk.

Therefore, the tangency portfolio embodies the trade-off between risk and return. Mathematically, the tangency portfolio maximizes the Sharpe ratio, defined as the excess return of a portfolio over the risk-free rate, divided by its standard deviation. This property ensures that the tangency portfolio offers the best possible risk-return trade-off among all risky portfolios.

### 2.2 Goals:

1. Create excess return time series for both sector and country indices.
2. Build rolling tangency portfolios using historical data.
3. Compare portfolio performance in terms of annual returns, Sharpe ratios, and weights.
4. Assess the stability of results through sensitivity tests, e.g., changing rebalancing frequency.

## 2.3 Methods

### Step 1: Data Preparation

- Retrieve daily return data for 18 sector indices and 18 country indices over a 10-year period using the Yahoo Finance API. Returns are already in USD as ETFs have been used.
- Compute **daily returns** using Adjusted Closing prices of each ETF.

  The risk-free rate time series was derived from the annualized returns of 3-month U.S. Treasury bills, which are widely regarded as a proxy for a risk-free asset, and then dividing by 252, the approximate number of trading days in a year. This approach ensures consistency in the calculation of daily returns.
- Subtract the risk-free rate to derive the DataFrames of excess returns.

  For this purpose, a function (*fetch_excess_returns(symbol, rf_series)*) that fetches financial data for a given symbol, calculates returns, and computes excess returns has been defined and implemented. The function takes as an input the ticker symbol of the ETFs and the pandas time series of the daily risk-free rates and returns a pandas DataFrame containing the daily excess returns of each ETF.

| SECTOR | XBI | XHE | XRT | XAR | XSD | XTN | XPH | IWY | IYE | IYM | IYR | XES | PSCH | XLF | XLV | XLY | XLP | XTL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2023-12-22 00:00:00 | 0.034634 | 0.004199 | -0.002975 | 0.011664 | 0.005319 | 0.005011 | 0.014638 | -0.000150 | 0.003159 | 0.005669 | 0.003109 | -0.001261 | 0.008690 | 0.001940 | 0.004780 | -0.007562 | 0.007433 | 0.005535 |
| 2023-12-26 00:00:00 | 0.020793 | 0.007855 | 0.009094 | 0.005696 | 0.015970 | 0.001799 | 0.008082 | 0.002365 | 0.008516 | 0.004986 | 0.007394 | 0.027245 | 0.008612 | 0.003811 | 0.002015 | 0.004028 | 0.004006 | 0.014511 |
| 2023-12-27 00:00:00 | 0.015106 | 0.004261 | 0.005431 | -0.000208 | -0.001211 | -0.004564 | 0.013332 | 0.001844 | -0.005086 | 0.001299 | 0.005040 | -0.008200 | 0.031684 | 0.002993 | 0.004005 | 0.003232 | 0.004407 | 0.000167 |
| 2023-12-28 00:00:00 | 0.000123 | 0.000027 | -0.000344 | -0.001821 | -0.003656 | -0.000444 | -0.002593 | -0.000264 | -0.014022 | -0.005293 | 0.005340 | -0.018393 | -0.004557 | 0.002718 | 0.002369 | -0.005404 | 0.000211 | 0.008792 |
| 2023-12-29 00:00:00 | -0.017485 | -0.013901 | -0.011011 | -0.005275 | -0.015451 | -0.012743 | -0.004988 | -0.003505 | -0.003369 | -0.005461 | -0.011562 | -0.009467 | -0.016071 | -0.003387 | 0.000822 | -0.006375 | 0.001881 | -0.009496 |

| COUNTRY | EWT | SPY | EWY | EWZ | EWW | EWC | EWJ | EWA | EZA | ENZL | THD | EIDO | EPHE | EWU | EWG | EWQ | EWI | INDY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2023-12-22 00:00:00 | 0.003404 | 0.001803 | -0.002546 | 0.008241 | -0.000796 | 0.007260 | 0.002961 | 0.002275 | -0.013763 | -0.001045 | 0.005371 | 0.002067 | 0.005592 | 0.003146 | -0.000884 | -0.001483 | 0.000980 | 0.000410 |
| 2023-12-26 00:00:00 | 0.020931 | 0.004016 | 0.004483 | 0.015103 | 0.007167 | 0.010774 | -0.000522 | 0.008044 | 0.005192 | 0.004616 | 0.006767 | 0.005692 | -0.000591 | 0.004958 | 0.005552 | 0.005927 | 0.007201 | 0.002875 |
| 2023-12-27 00:00:00 | 0.009702 | 0.001600 | 0.008817 | 0.003206 | 0.001988 | 0.000878 | 0.005321 | 0.004702 | 0.024200 | 0.006470 | 0.006245 | 0.004754 | -0.004437 | 0.003721 | 0.005518 | 0.003348 | 0.004204 | 0.009417 |
| 2023-12-28 00:00:00 | 0.003500 | 0.000171 | 0.017218 | -0.004743 | -0.007511 | -0.004818 | 0.005762 | -0.003057 | -0.024749 | 0.006426 | 0.002920 | -0.002451 | 0.005971 | -0.005325 | -0.006905 | -0.009825 | -0.006942 | 0.004661 |
| 2023-12-29 00:00:00 | -0.000206 | -0.003100 | -0.007026 | -0.004478 | -0.001824 | -0.000751 | 0.001356 | -0.006330 | 0.020556 | -0.001441 | -0.004726 | 0.003843 | -0.002892 | -0.000206 | 0.000806 | 0.001072 | 0.000089 | -0.006059 |

### Step 2: Rolling Tangency Portfolio Construction and Performance Metrics

The analysis utilized a rolling four-year period to construct and evaluate tangency portfolios. A function (*calculate_tangency_portfolio(mean_returns, cov_matrix)*) was developed to minimize the negative of the Sharpe ratio (which is mathematically the same as maximizing the Sharpe ratio), optimizing the portfolio weights under two constraints: the weights should sum to one and short selling is not allowed, which means that weights should be non-negative. The function takes as an input the array of mean returns, the covariance matrix and the risk-free rate for the period. The function returns the weights of the Tangency Portfolio. The Sequential Least Squares Quadratic Programming (SLSQP) method was applied for optimization.

The process involved calculating mean returns, the covariance matrix, and the risk-free rate for each four-year interval. The tangency portfolio's weights, returns, risk, and Sharpe ratio, along with the minimum variance portfolio and efficient frontier, were determined for each period. Together, these concepts provide a framework for constructing portfolios that balance risk and return effectively.

The rolling analysis described has been repeated iteratively across the dataset using a *for* loop, rebalancing the portfolio annually based on updated calculations.

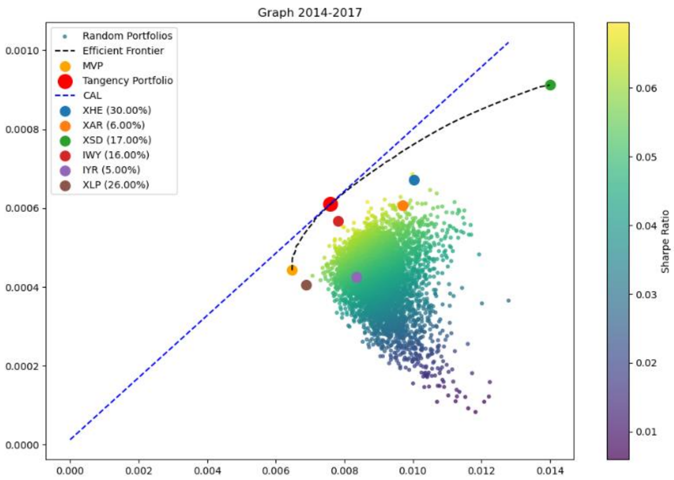
For purposes of significance, the graphs highlight the significant ETFs in the tangency portfolio, defined as those with weights exceeding a threshold of 0.001. This ensures that only ETFs with a meaningful impact on the portfolio's composition are easily identifiable.

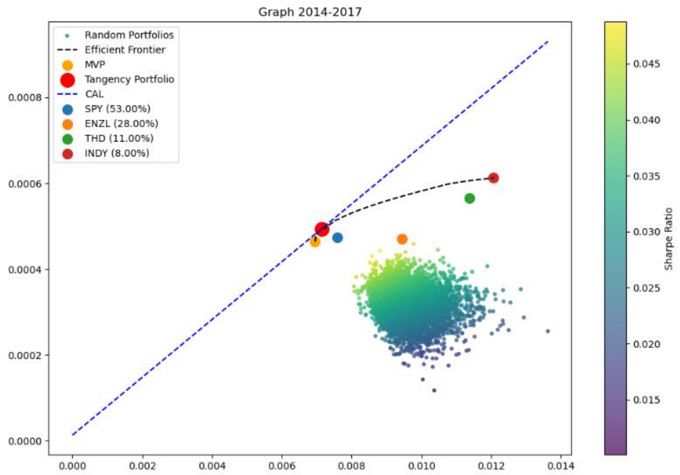
Each graph is related to a four-years period and plots the tangency portfolio as the tangency point between the efficient frontier and capital market line (CML).

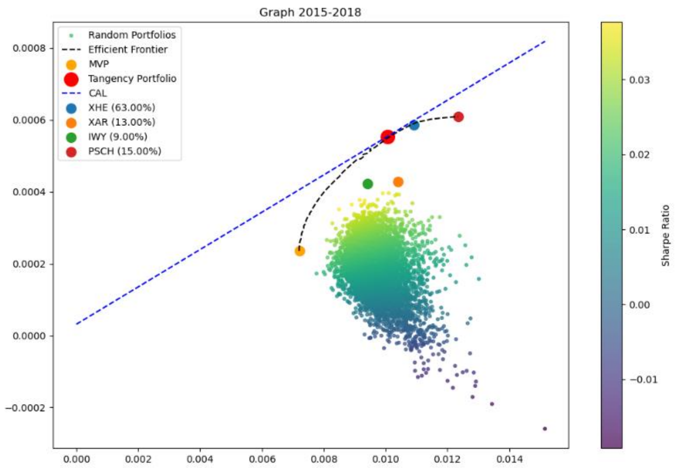
The efficient frontier was calculated implementing a function that takes as input the array of mean returns, the covariance matrix, and the return of the minimum variance portfolio, which was itself computed using an appropriately implemented function within the code.

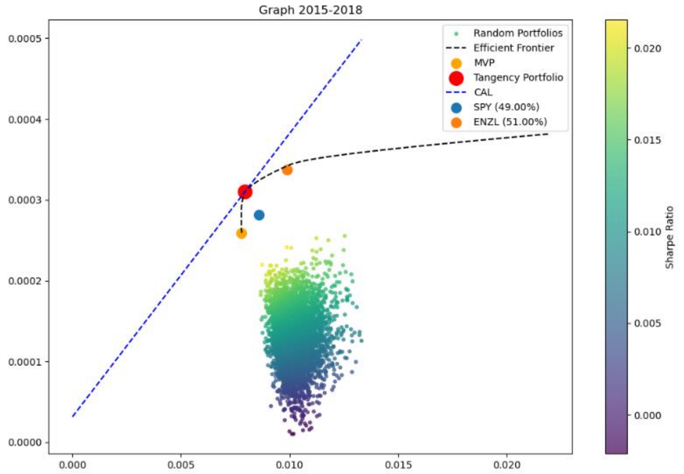
A set of random portfolios was then generated by assigning random weights to the various ETFs taken into consideration. As anticipated, these portfolios are positioned below the Efficient Frontier, meaning that they are not optimized for risk and return.

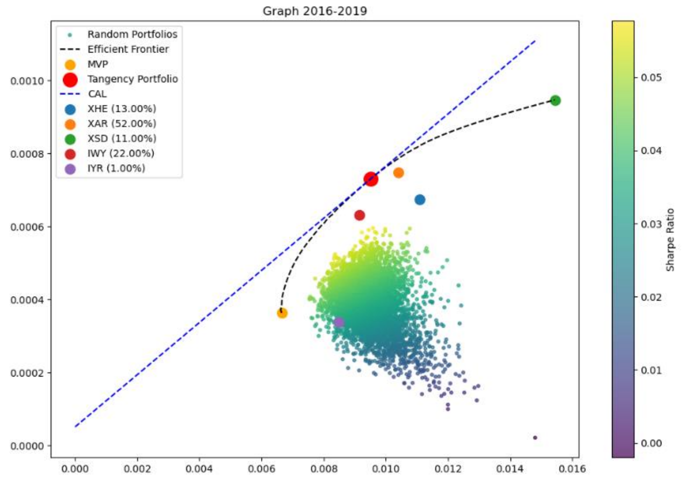
The graph below illustrates a comparison of the frontier by sector (left) and by country (right) across each four-year period.

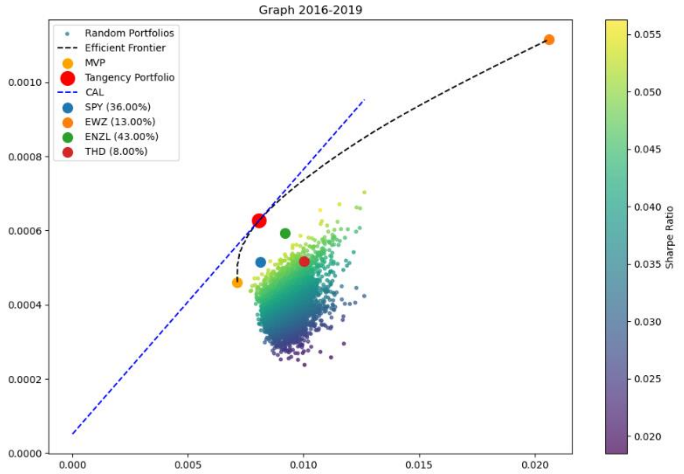


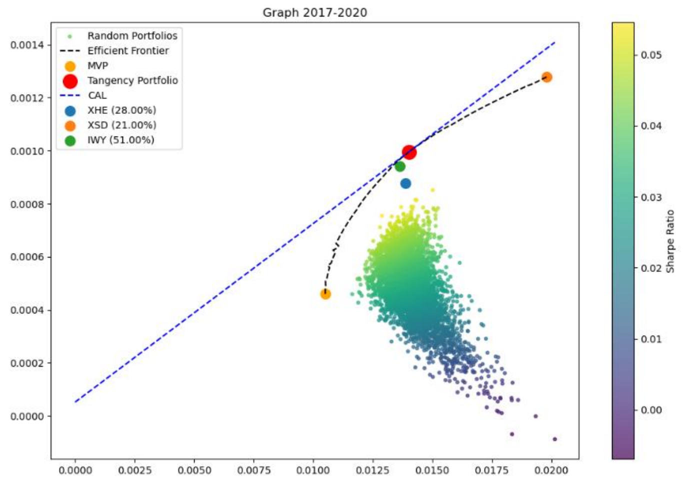



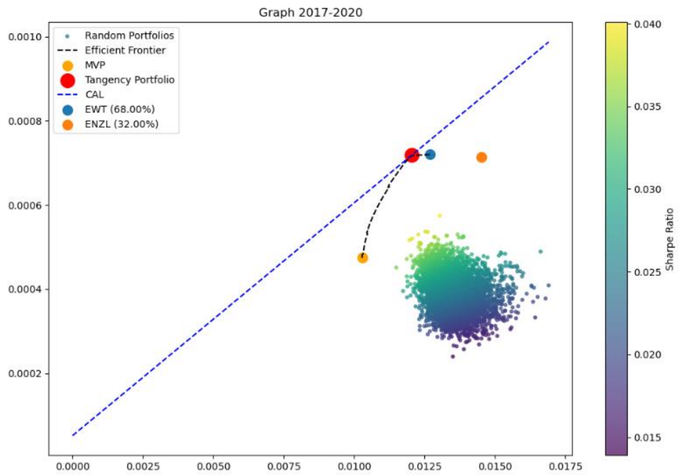

Graph 2015-2018
Random Portfolios
Efficient Frontier
MVP
Tangency Portfolio
CAL
XHE (63.00%)
XAR (13.00%)
IWY (9.00%)
PSCH (15.00%)
Sharpe Ratio

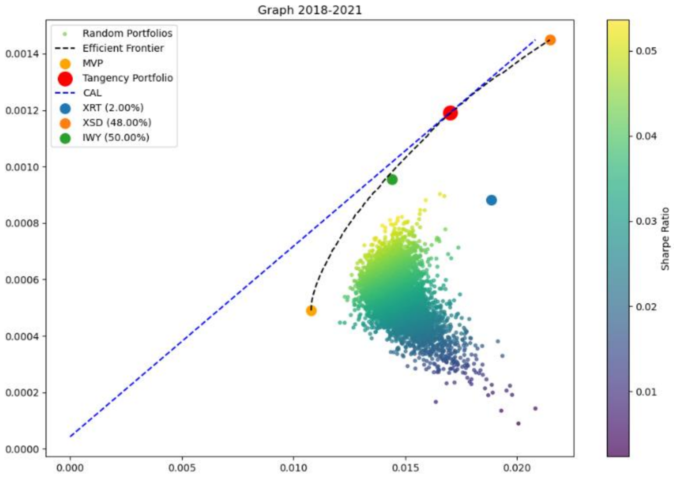

Graph 2015-2018
Random Portfolios
Efficient Frontier
MVP
Tangency Portfolio
CAL
SPY (49.00%)
ENZL (51.00%)
Sharpe Ratio

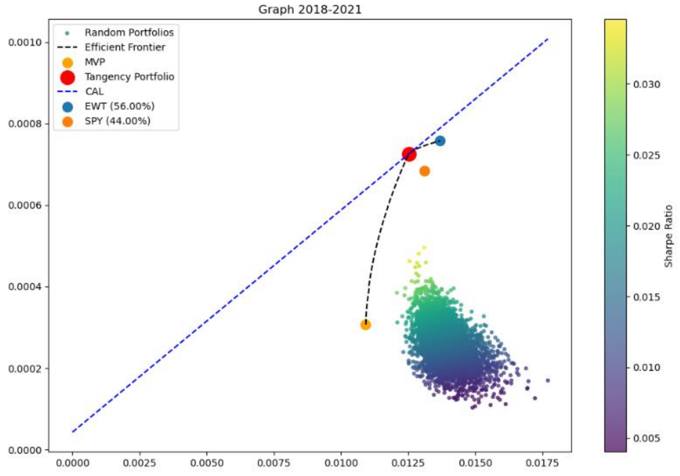

Graph 2016-2019
Random Portfolios
Efficient Frontier
MVP
Tangency Portfolio
CAL
XHE (13.00%)
XAR (52.00%)
XSD (11.00%)
IWY (22.00%)
IYR (1.00%)
Sharpe Ratio

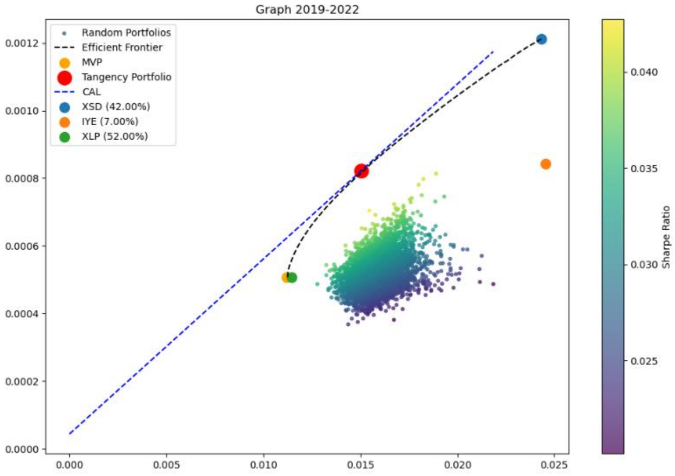

Graph 2016-2019
Random Portfolios
Efficient Frontier
MVP
Tangency Portfolio
CAL
SPY (36.00%)
EWZ (13.00%)
ENZL (43.00%)
THD (8.00%)
Sharpe Ratio

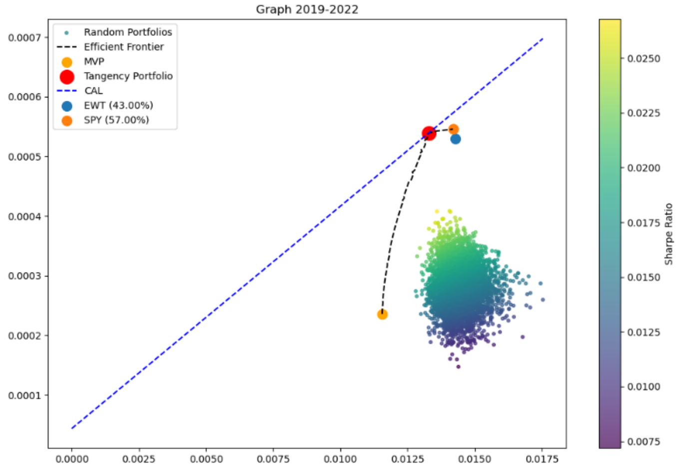

Graph 2017-2020
Random Portfolios
Efficient Frontier
MVP
Tangency Portfolio
CAL
XHE (28.00%)
XSD (21.00%)
IWY (51.00%)
Sharpe Ratio


Graph 2017-2020
Random Portfolios
Efficient Frontier
MVP
Tangency Portfolio
CAL
EWT (68.00%)
ENZL (32.00%)
Sharpe Ratio




**Metrics computed**:

- Annual Returns: $R_t = totR_{t+1} - totR_t$
- Sharpe Ratio: $S = \frac{mean\, portfolio\, return - risk\, free\, rate}{portfolio\, stdev}$
- Portfolio Weights: $w = \frac{V^{-1}(\mu - r_f)}{1^T V^{-1}(\mu - r_f)}$

### Step 3: Sensitivity Testing

To assess stability, the analysis of tangency portfolios was repeated with one key modification: portfolio rebalancing was conducted quarterly instead of annually.

Sector:

| | Rolling Period | Investment Period | Tangency Weights | Sharpe Ratio |
|---|---|---|---|---|
| 0 | 2014-01-01 to 2017-12-31 | 2018-01-01 to 2018-03-31 | {'XHE': 0.29, 'XAR': 0.06, 'XSD': 0.16, 'IWY': 0.16, 'IYR': 0.05, 'XLP': 0.27} | 0.080400 |
| 1 | 2014-04-01 to 2018-03-31 | 2018-04-01 to 2018-06-30 | {'XHE': 0.43, 'XAR': 0.13, 'XSD': 0.01, 'IWY': 0.39, 'PSCH': 0.04} | 0.076300 |
| 2 | 2014-07-01 to 2018-06-30 | 2018-07-01 to 2018-09-30 | {'XHE': 0.57, 'XAR': 0.16, 'IWY': 0.09, 'PSCH': 0.1, 'XLY': 0.08} | 0.083200 |
| 3 | 2014-10-01 to 2018-09-30 | 2018-10-01 to 2018-12-31 | {'XHE': 0.68, 'XAR': 0.29, 'XLY': 0.03} | 0.098700 |
| 4 | 2015-01-01 to 2018-12-31 | 2019-01-01 to 2019-03-31 | {'XHE': 0.61, 'XAR': 0.14, 'IWY': 0.12, 'PSCH': 0.12} | 0.055000 |
| 5 | 2015-04-01 to 2019-03-31 | 2019-04-01 to 2019-06-30 | {'XHE': 0.46, 'XAR': 0.15, 'IWY': 0.39} | 0.060100 |
| 6 | 2015-07-01 to 2019-06-30 | 2019-07-01 to 2019-09-30 | {'XHE': 0.33, 'XAR': 0.43, 'IWY': 0.14, 'IYR': 0.07, 'XLP': 0.03} | 0.066500 |
| 7 | 2015-10-01 to 2019-09-30 | 2019-10-01 to 2019-12-31 | {'XHE': 0.15, 'XAR': 0.54, 'XSD': 0.08, 'IYR': 0.12, 'XLP': 0.11} | 0.080000 |
| 8 | 2016-01-01 to 2019-12-31 | 2020-01-01 to 2020-03-31 | {'XHE': 0.12, 'XAR': 0.47, 'XSD': 0.08, 'IWY': 0.24, 'IYR': 0.03, 'XLP': 0.07} | 0.077000 |
| 9 | 2016-04-01 to 2020-03-31 | 2020-04-01 to 2020-06-30 | {'XHE': 0.52, 'XSD': 0.16, 'IWY': 0.32} | 0.046200 |
| 10 | 2016-07-01 to 2020-06-30 | 2020-07-01 to 2020-09-30 | {'XHE': 0.06, 'XSD': 0.16, 'IWY': 0.77} | 0.060200 |
| 11 | 2016-10-01 to 2020-09-30 | 2020-10-01 to 2020-12-31 | {'IWY': 1.0} | 0.064400 |
| 12 | 2017-01-01 to 2020-12-31 | 2021-01-01 to 2021-03-31 | {'XHE': 0.26, 'XSD': 0.18, 'IWY': 0.56} | 0.071100 |
| 13 | 2017-04-01 to 2021-03-31 | 2021-04-01 to 2021-06-30 | {'XHE': 0.12, 'XRT': 0.18, 'XSD': 0.31, 'IWY': 0.38, 'PSCH': 0.02} | 0.066400 |
| 14 | 2017-07-01 to 2021-06-30 | 2021-07-01 to 2021-09-30 | {'XRT': 0.25, 'XSD': 0.18, 'IWY': 0.56} | 0.070400 |
| 15 | 2017-10-01 to 2021-09-30 | 2021-10-01 to 2021-12-31 | {'XRT': 0.18, 'XSD': 0.25, 'IWY': 0.57} | 0.066700 |
| 16 | 2018-01-01 to 2021-12-31 | 2022-01-01 to 2022-03-31 | {'XRT': 0.03, 'XSD': 0.43, 'IWY': 0.54} | 0.070100 |
| 17 | 2018-04-01 to 2022-03-31 | 2022-04-01 to 2022-06-30 | {'XSD': 0.36, 'IWY': 0.28, 'XLV': 0.09, 'XLP': 0.27} | 0.062100 |
| 18 | 2018-07-01 to 2022-06-30 | 2022-07-01 to 2022-09-30 | {'XSD': 0.3, 'XLV': 0.21, 'XLP': 0.5} | 0.048900 |
| 19 | 2018-10-01 to 2022-09-30 | 2022-10-01 to 2022-12-31 | {'XSD': 0.53, 'XLP': 0.47} | 0.041600 |
| 20 | 2019-01-01 to 2022-12-31 | 2023-01-01 to 2023-03-31 | {'XSD': 0.38, 'IYE': 0.06, 'XLV': 0.01, 'XLP': 0.55} | 0.054700 |
| 21 | 2019-04-01 to 2023-03-31 | 2023-04-01 to 2023-06-30 | {'XSD': 0.61, 'XLP': 0.39} | 0.051700 |
| 22 | 2019-07-01 to 2023-06-30 | 2023-07-01 to 2023-09-30 | {'XSD': 0.68, 'IYE': 0.0, 'XLV': 0.14, 'XLP': 0.18} | 0.050200 |
| 23 | 2019-10-01 to 2023-09-30 | 2023-10-01 to 2023-12-31 | {'XSD': 0.34, 'IWY': 0.25, 'IYE': 0.23, 'XLV': 0.18} | 0.045500 |

Country:

| | Rolling Period | Investment Period | Tangency Weights | Sharpe Ratio |
|---|---|---|---|---|
| 0 | 2014-01-01 to 2017-12-31 | 2018-01-01 to 2018-03-31 | {'SPY': 0.54, 'ENZL': 0.28, 'THD': 0.11, 'INDY': 0.07} | 0.069100 |
| 1 | 2014-04-01 to 2018-03-31 | 2018-04-01 to 2018-06-30 | {'SPY': 0.66, 'ENZL': 0.22, 'THD': 0.13} | 0.057700 |
| 2 | 2014-07-01 to 2018-06-30 | 2018-07-01 to 2018-09-30 | {'SPY': 0.74, 'ENZL': 0.26} | 0.054200 |
| 3 | 2014-10-01 to 2018-09-30 | 2018-10-01 to 2018-12-31 | {'SPY': 0.7, 'ENZL': 0.3} | 0.063400 |
| 4 | 2015-01-01 to 2018-12-31 | 2019-01-01 to 2019-03-31 | {'SPY': 0.51, 'ENZL': 0.49} | 0.039000 |
| 5 | 2015-04-01 to 2019-03-31 | 2019-04-01 to 2019-06-30 | {'SPY': 0.51, 'EWZ': 0.0, 'ENZL': 0.49} | 0.054000 |
| 6 | 2015-07-01 to 2019-06-30 | 2019-07-01 to 2019-09-30 | {'SPY': 0.35, 'ENZL': 0.65} | 0.066600 |
| 7 | 2015-10-01 to 2019-09-30 | 2019-10-01 to 2019-12-31 | {'SPY': 0.38, 'EWZ': 0.06, 'ENZL': 0.55, 'THD': 0.02} | 0.076500 |
| 8 | 2016-01-01 to 2019-12-31 | 2020-01-01 to 2020-03-31 | {'SPY': 0.38, 'EWZ': 0.11, 'ENZL': 0.42, 'THD': 0.09} | 0.077800 |
| 9 | 2016-04-01 to 2020-03-31 | 2020-04-01 to 2020-06-30 | {'EWT': 0.28, 'SPY': 0.67, 'ENZL': 0.05} | 0.028600 |
| 10 | 2016-07-01 to 2020-06-30 | 2020-07-01 to 2020-09-30 | {'EWT': 0.44, 'SPY': 0.38, 'ENZL': 0.18} | 0.042700 |
| 11 | 2016-10-01 to 2020-09-30 | 2020-10-01 to 2020-12-31 | {'EWT': 0.32, 'SPY': 0.68} | 0.044500 |
| 12 | 2017-01-01 to 2020-12-31 | 2021-01-01 to 2021-03-31 | {'EWT': 0.68, 'ENZL': 0.32} | 0.059600 |
| 13 | 2017-04-01 to 2021-03-31 | 2021-04-01 to 2021-06-30 | {'EWT': 0.74, 'SPY': 0.23, 'ENZL': 0.03} | 0.056800 |
| 14 | 2017-07-01 to 2021-06-30 | 2021-07-01 to 2021-09-30 | {'EWT': 0.55, 'SPY': 0.45} | 0.057000 |
| 15 | 2017-10-01 to 2021-09-30 | 2021-10-01 to 2021-12-31 | {'EWT': 0.54, 'SPY': 0.46} | 0.053800 |
| 16 | 2018-01-01 to 2021-12-31 | 2022-01-01 to 2022-03-31 | {'EWT': 0.56, 'SPY': 0.44} | 0.057900 |
| 17 | 2018-04-01 to 2022-03-31 | 2022-04-01 to 2022-06-30 | {'EWT': 0.36, 'SPY': 0.64} | 0.051400 |
| 18 | 2018-07-01 to 2022-06-30 | 2022-07-01 to 2022-09-30 | {'EWT': 0.57, 'SPY': 0.43} | 0.036800 |
| 19 | 2018-10-01 to 2022-09-30 | 2022-10-01 to 2022-12-31 | {'EWT': 0.12, 'SPY': 0.43, 'INDY': 0.46} | 0.025900 |
| 20 | 2019-01-01 to 2022-12-31 | 2023-01-01 to 2023-03-31 | {'EWT': 0.44, 'SPY': 0.56} | 0.040600 |
| 21 | 2019-04-01 to 2023-03-31 | 2023-04-01 to 2023-06-30 | {'EWT': 0.66, 'SPY': 0.27, 'EWW': 0.06} | 0.039800 |
| 22 | 2019-07-01 to 2023-06-30 | 2023-07-01 to 2023-09-30 | {'EWT': 0.61, 'SPY': 0.32, 'EWW': 0.06} | 0.041600 |
| 23 | 2019-10-01 to 2023-09-30 | 2023-10-01 to 2023-12-31 | {'EWT': 0.5, 'SPY': 0.39, 'EWW': 0.11} | 0.035500 |

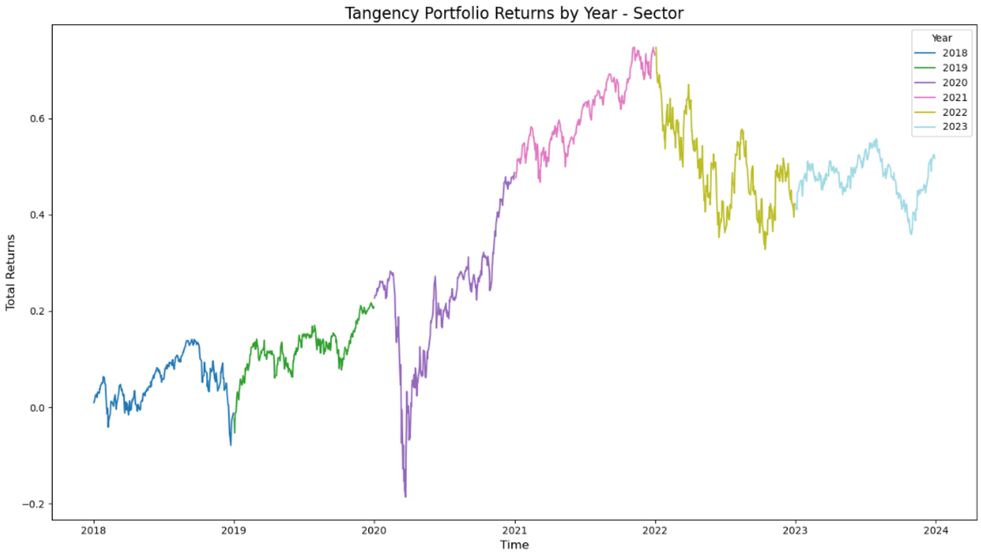
The final output includes time series plots for the three periods, a summary of returns for each interval, and the final total returns.

## 3. Results

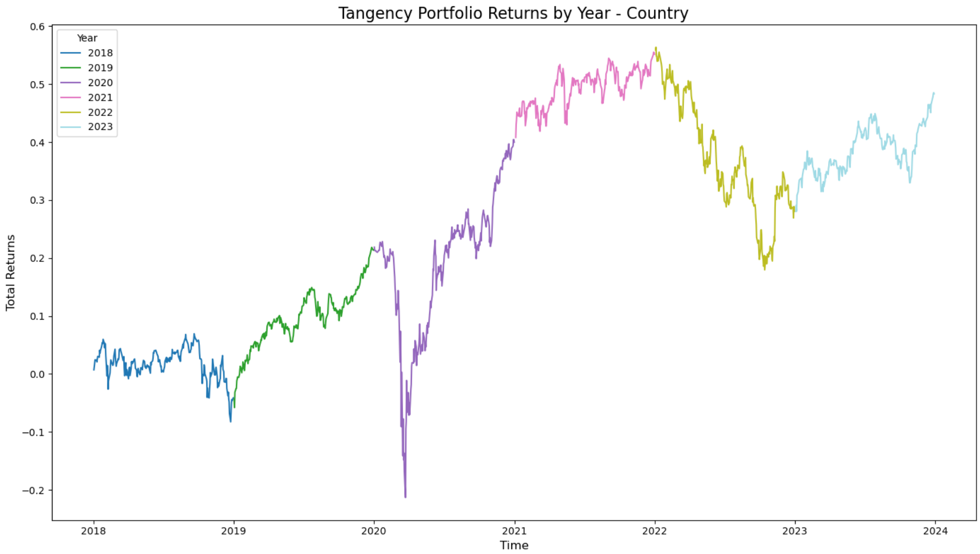
### 1. **Annual Returns**:

- Time series of annual returns for sector-based and country-based portfolios.

Four Years Periods, Sectors (top) and Country (bottom):

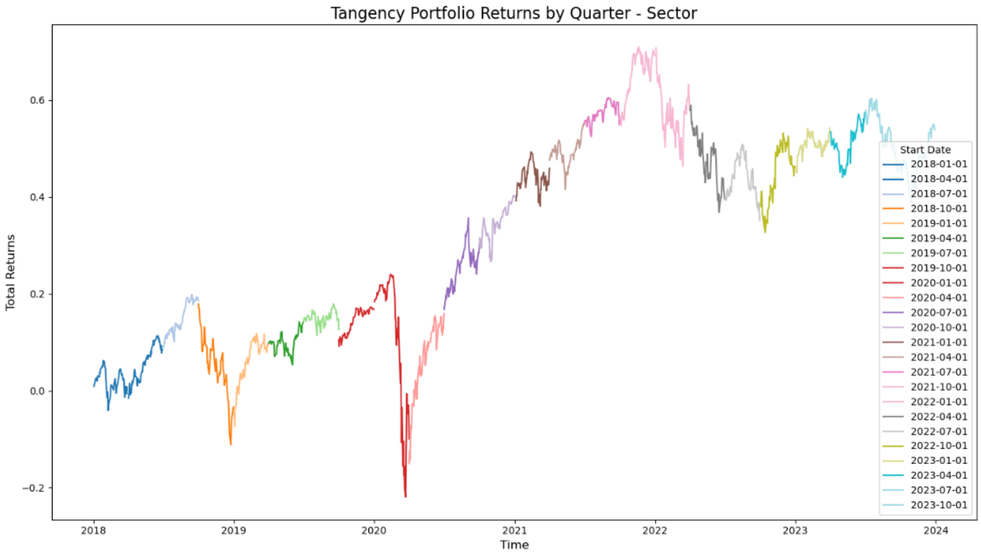



```
Year 2018: Return = -0.0136
Year 2019: Return = 0.2236
Year 2020: Return = 0.2671
Year 2021: Return = 0.2454
Year 2022: Return = -0.3112
Year 2023: Return = 0.0809
Final Total Return: 0.4923
```

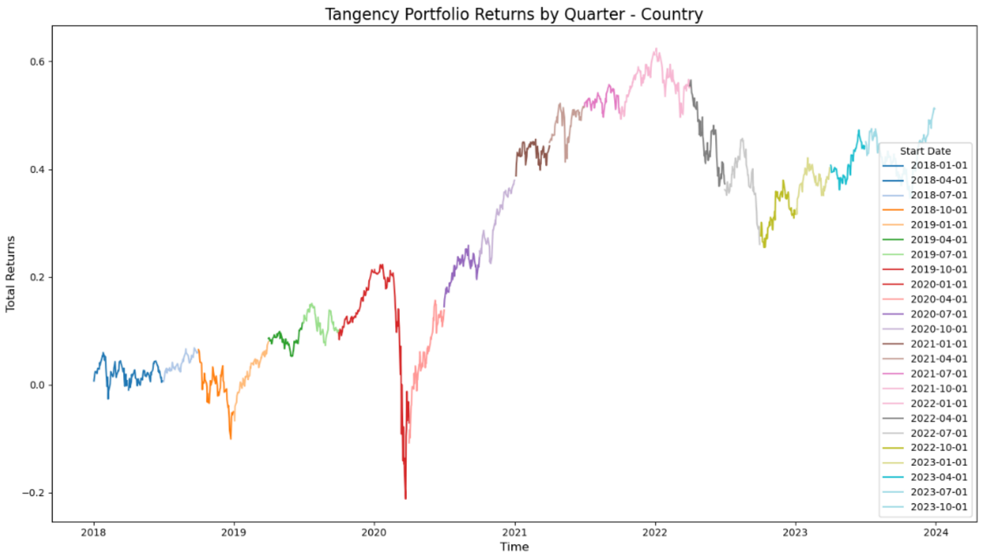



```
Year 2018: Return = -0.0413
Year 2019: Return = 0.2551
Year 2020: Return = 0.1882
Year 2021: Return = 0.1518
Year 2022: Return = -0.2708
Year 2023: Return = 0.2029
Final Total Return: 0.4860
```

Three Months Periods, Sectors (top) and Country (bottom):




```
Period 2018-01-01: Return = 0.0069
Period 2018-04-01: Return = 0.0776
Period 2018-07-01: Return = 0.1017
Period 2018-10-01: Return = -0.2200
Period 2019-01-01: Return = 0.1290
Period 2019-04-01: Return = 0.0470
Period 2019-07-01: Return = -0.0160
Period 2019-10-01: Return = 0.0417
Period 2020-01-01: Return = -0.2676
Period 2020-04-01: Return = 0.2584
Period 2020-07-01: Return = 0.1452
Period 2020-10-01: Return = 0.0990
Period 2021-01-01: Return = 0.0561
Period 2021-04-01: Return = 0.0907
Period 2021-07-01: Return = 0.0094
Period 2021-10-01: Return = 0.1333
Period 2022-01-01: Return = -0.1097
Period 2022-04-01: Return = -0.1864
Period 2022-07-01: Return = -0.0446
Period 2022-10-01: Return = 0.1105
Period 2023-01-01: Return = 0.0804
Period 2023-04-01: Return = 0.0316
Period 2023-07-01: Return = -0.1047
Period 2023-10-01: Return = 0.0696
Final Total Return: 0.5391
```




```
Period 2018-01-01: Return = 0.0077
Period 2018-04-01: Return = -0.0005
Period 2018-07-01: Return = 0.0550
Period 2018-10-01: Return = -0.1120
Period 2019-01-01: Return = 0.1298
Period 2019-04-01: Return = 0.0358
Period 2019-07-01: Return = -0.0162
Period 2019-10-01: Return = 0.1090
Period 2020-01-01: Return = -0.2793
Period 2020-04-01: Return = 0.2093
Period 2020-07-01: Return = 0.1004
Period 2020-10-01: Return = 0.1402
Period 2021-01-01: Return = 0.0637
Period 2021-04-01: Return = 0.0726
Period 2021-07-01: Return = -0.0075
Period 2021-10-01: Return = 0.1040
Period 2022-01-01: Return = -0.0596
Period 2022-04-01: Return = -0.1798
Period 2022-07-01: Return = -0.1120
Period 2022-10-01: Return = 0.0560
Period 2023-01-01: Return = 0.0859
Period 2023-04-01: Return = 0.0399
Period 2023-07-01: Return = -0.0575
Period 2023-10-01: Return = 0.1269
Final Total Return: 0.5119
```

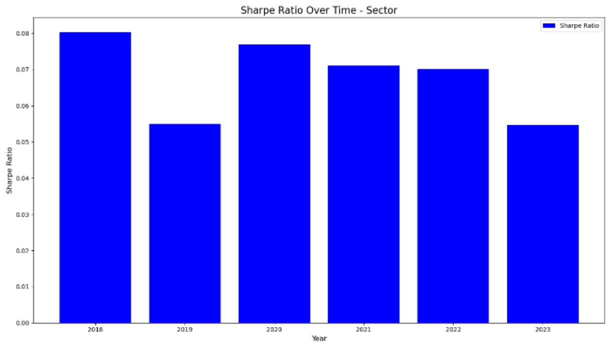
The small discontinuities visible in the graph are attributable to rebalancing occurring on market closure days.

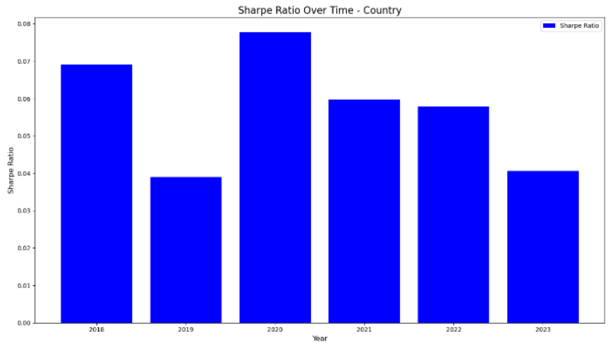
Over the observed period, the Total Return of the Tangency Portfolio diversified by Sector consistently outperforms the portfolio diversified by Country under both quarterly and yearly rebalancing strategies (49.23% vs 48.60% and 53.91% vs 51.19%, respectively).

Additionally, quarterly rebalancing yields higher returns than yearly rebalancing in both diversification approaches.

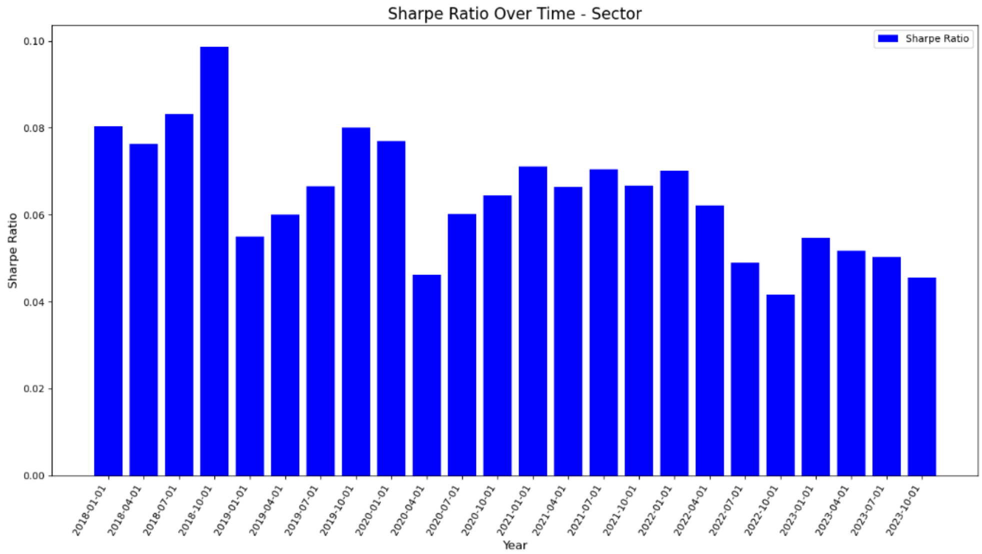
2. **Sharpe Ratios**:
    - Comparison of risk-adjusted returns for both diversification strategies.

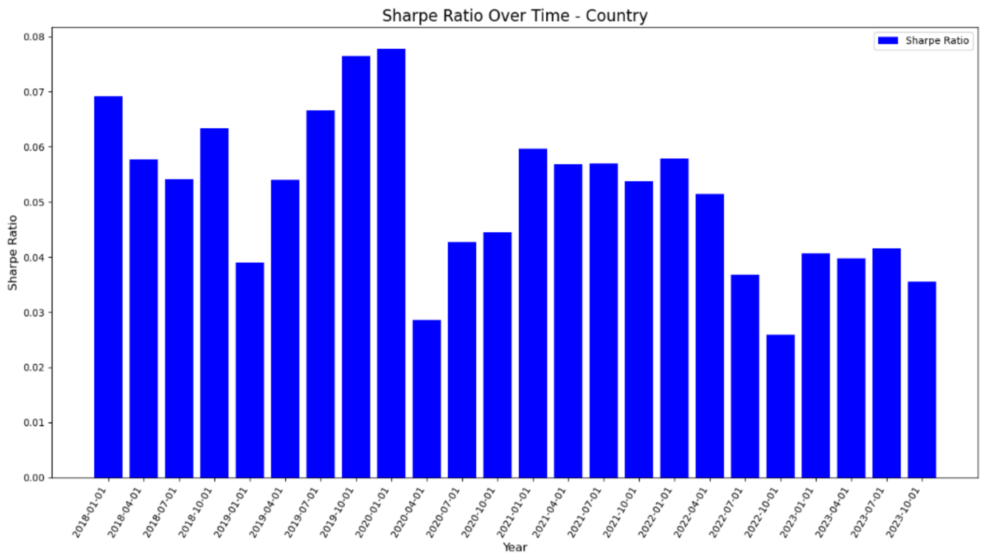
Four Years Periods, Sectors (left) and Country (right):




Three Months Periods, Sectors (top) and Country (bottom):



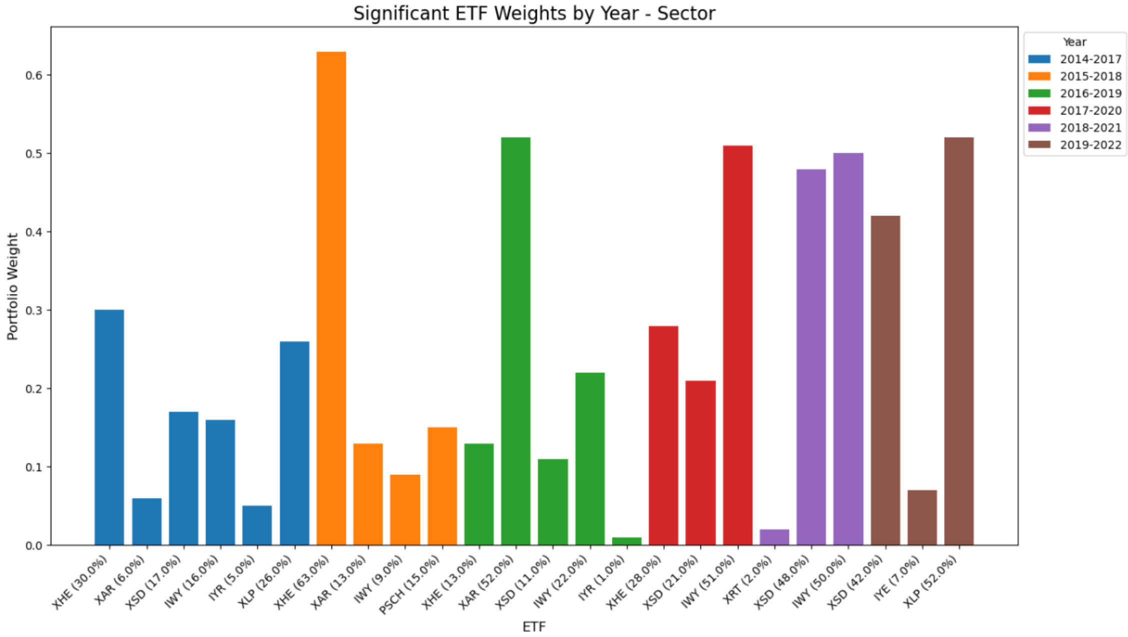
The analysis of Sharpe ratio levels confirms that sector diversification outperforms country diversification. Specifically, sector diversification achieves an average Sharpe ratio of approximately 6.8%, compared to an average of 5.7% for country diversification, under yearly rebalancing.

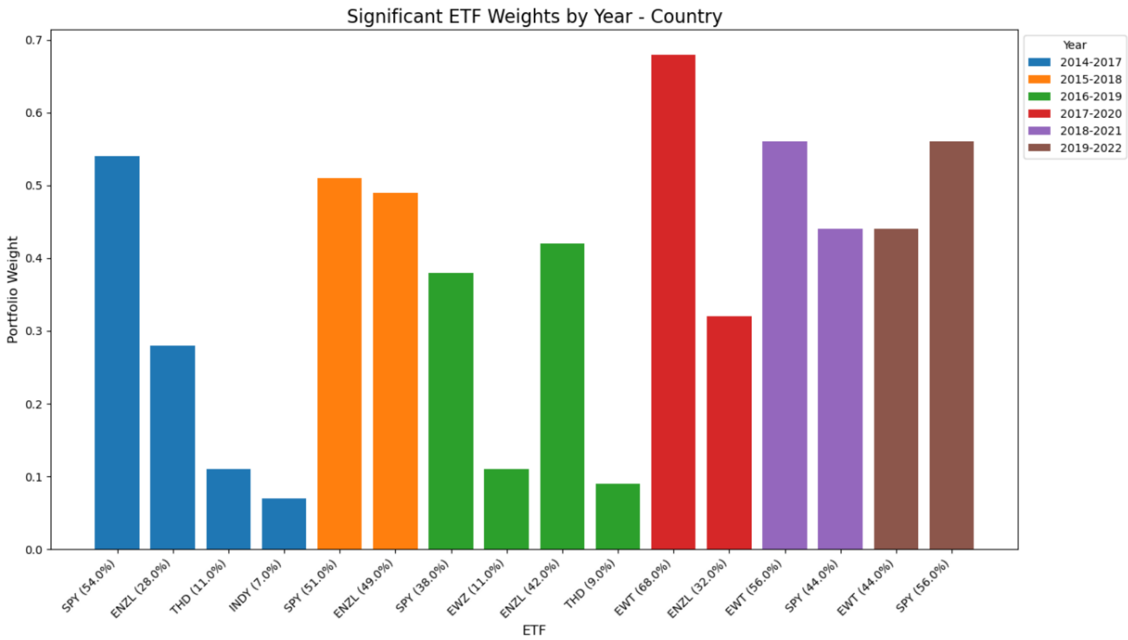
It is important to highlight that these Sharpe ratios have been obtained in “daily” terms, meaning that daily returns have been used for the computation. To annualize these values, the daily Sharpe ratios are multiplied by the square root of the number of trading days in a year (252).

This adjustment returns annualized Sharpe ratios of 107% and 91% respectively, which are consistent with the expected outcomes.

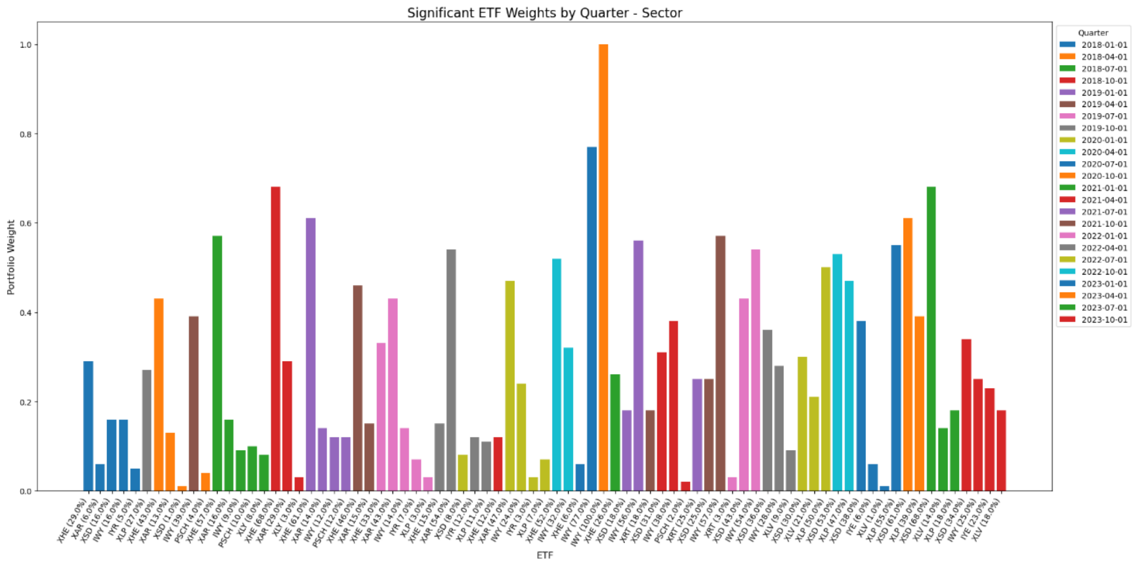
3. **Portfolio Weights**:
    - Visualization of how weights evolve over time, showing reliance on specific sectors or countries.

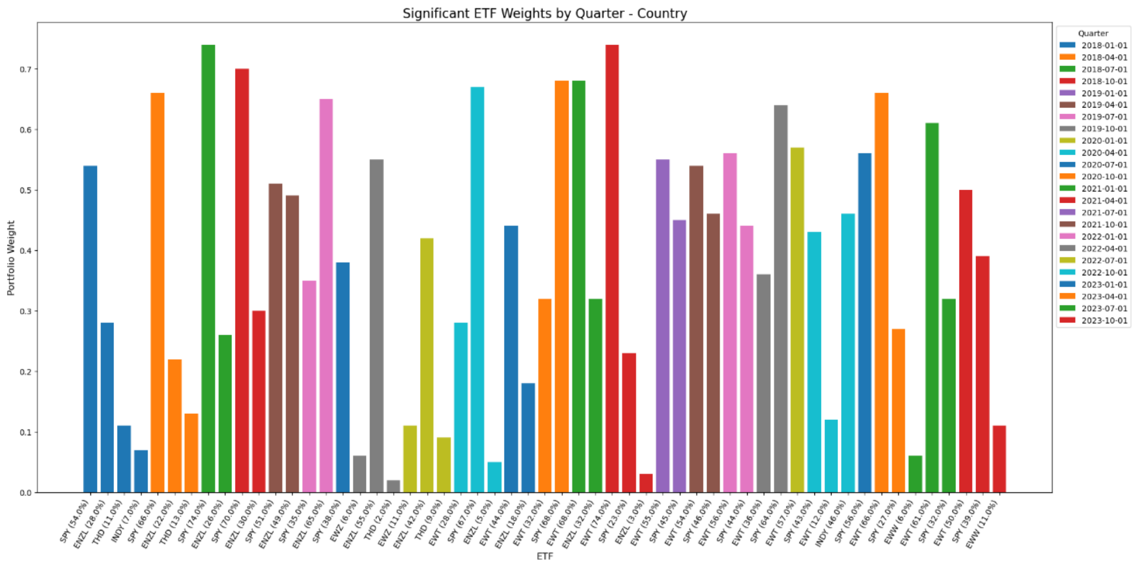
Four Years Periods, Sectors (top) and Country (bottom):



Three Months Periods, Sectors (top) and Country (bottom):




The bar charts show that, in each period, the Sector Tangency Portfolio includes a greater number of ETFs compared to the Country Tangency Portfolio, offering a higher level of diversification. This is a consequence of the fact that, within the Country data, certain ETFs consistently outperform others, resulting in substantial weights in the Tangency Portfolio (e.g., SPY, EWT) after each rebalancing.

On the other hand, the performance of Sector ETFs appears more balanced and likely includes some negatively correlated assets, as different industries are exposed to different types of risks, leading to higher diversification and, consequently, lower volatility.

## 4. Key Observations

1. **Performance**:

   The goal of Country diversification is to minimize exposure to macro risks like country-specific political instability, currency devaluation, or recessions investing in assets across multiple countries and regions.

   Sector diversification aims to minimize exposure to micro risks, which are risks tied to individual industries, such as industry-specific economic downturns or sectoral disruptions, avoiding over-reliance on a single sector's performance.

   Sector-based portfolios may outperform during periods of global economic stability, while country-based portfolios provide better diversification during economic downturns due to the different nature of risk involved.

   It is important to recognize that country-based portfolios can often be significantly exposed to the S&P 500, thus exhibiting similar characteristics to US sector-based portfolios. This reduces the distinction between a sectoral diversification and a geographical diversification in terms of performance, as both strategies are subject to similar global market dynamics.

   Despite this, over the past 10 years, a slightly better performance is observed for the sector-diversified portfolio. This preference is further supported when comparing the Sharpe ratios of the two portfolios, with the sector diversification consistently showing a higher value.

   The reason could be identified in several key factors. The US experienced a strong post-financial crisis recovery, with innovation and technological advancement, resulting in the Technology Boom, driving much of the economic growth.

   Additionally, industries like healthcare also saw substantial growth, supported by demographic trends and accelerated during Covid-19 pandemic.

   On the other hand, many international markets underperformed due to political uncertainty (Brexit), wars and crises (Covid-19) that resulted in a slower economic growth compared to the US market.

2. **Stability**:

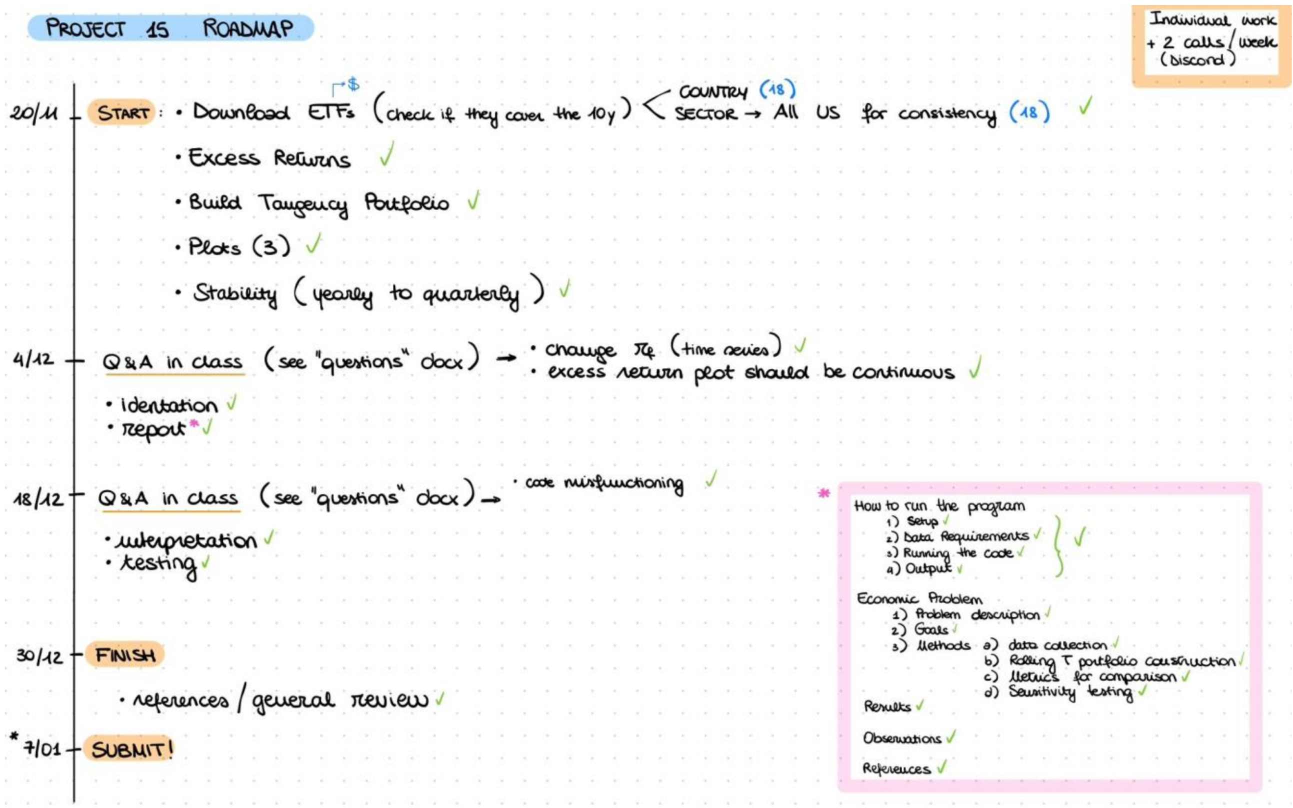
   Quarterly rebalancing tends to produce more stable and consistent portfolio returns compared to annual rebalancing, limiting the impact of market fluctuations and ensuring that the portfolio stays close to its target allocation.

   Portfolios rebalanced quarterly have shown better performances than portfolios rebalanced annually both for sector diversification and for country diversification.

   Higher frequency of trades results in an increase of transaction costs, which have been ignored for the purpose of the project.

## 5. References and Sources


- Financial indices and T-Bill: Yahoo Finance.
- Portfolio Optimization methods: Markowitz portfolio theory, Sharpe performance analysis.
- Portfolio Optimization library: https://pyportfolioopt.readthedocs.io/
- Reuters


## 6. Author's declaration:

We hereby certify that

- We have written the program ourselves except for clearly marked pieces of code and mentions of Generative AI
- We have tested the program, and it ran without crashing


| | | |
|---|---|---|
| Leonardo Zoccolillo | 24-986-861 | leonardo.zoccolillo@usi.ch |
| Davide Poma | 24-987-273 | davide.poma@usi.ch |
| Federica Filograsso | 24-987-422 | federica.filograsso@usi.ch |