

Enhanced Passive Investing - Harry Browne Permanent Portfolio with Forex Strategies

COMP4971C - Independent Work (Spring 2020)

Chih-yu LEE (Supervised by Dr. David Rossiter, HKUST)

Abstract

The Permanent Portfolio, an investment portfolio devised by investment analyst Harry Browne in 1980s, is a remarkable all weather portfolio since it is proposed in 1980s. From 1976 to 2016, its annual return was 8.65% and the volatility was 7.20% while a standard 60/40 portfolio had 10.13% annual return with 9.60% volatility. It is known to be an appealing option for risk-averse investors. Nonetheless, we discovered that it could have a 8% monthly loss in the 2007-2008 Global Financial Crisis and we would like to revise it by introducing the forex strategies into the portfolio.

In this project, we assessed several forex strategies and selected Momentum and Carry Trade into our portfolio. Finally, we found that the portfolio with equal weights in all 4 components in Permanent Portfolio and 2 forex strategies can produce an annual return of 6.43% with Sharpe Ratio 1.002 while the Max Drawdown is merely 7.40% over 16 years, which the Max Drawdown is a half of the one in the original Permanent Portfolio.

Contents

1 Introduction	4
2 Preliminary Settings and Methodologies	4
2.1 Setup	4
2.1.1 Platform and Programming Language Used	4
2.1.2 Data Sources and Trading Signals	4
2.2 Algorithm Framework	5
2.2.1 Construction of Harry Browne Permanent Portfolio	5
2.2.2 Forex Strategies	6
2.2.3 Evaluation Metrics	6
3 Backtesting Results	10
3.1 Forex Carry Trade (FCT)	11
3.1.1 Important terminologies	11
3.1.2 Weight in the currency pairs	12
3.2 Forex Momentum (MOM)	15
3.2.1 Number of currencies with strong momentum to long	15
3.2.2 Possibility of short currencies with top lowest momentum	18
3.3 Evaluation of the weight for 4 components and 2 strategies	19
4 Execution: 1-Month Paper Trading via the Interactive Brokers	22
4.1 Performance Analysis	22
4.2 Breakdown for each component and strategy	25
4.2.1 The pair in FCT	25
4.2.2 USD/MXN in MOM	27
4.2.3 USD/HUF in MOM	29
4.2.4 SPY	31
4.2.5 TLT	33
4.2.6 GLD	35
4.2.7 SHY	37
4.3 Comparison with the backtest result on QuantConnect	39
4.4 Cost Analysis	40
4.4.1 Borrowing Cost	40

4.4.2 Commission Fee	40
4.4.3 Latency	41
5 Conclusion	42
6 Future Work	43
7 References	44
8 Appendices	45
Appendix A: Further Investigations on number of currency pairs to long/short in FCT .	45
A-1 Long and short 2 pairs of currencies with %GE = 200%	45
A-2 Long and short 3 pairs of currencies with %GE = 200%	46
Appendix B: The full result of all 63 possible portfolios in Section 3.3	47
Appendix C: Complete information of the optimal portfolio	49

1 Introduction

In this research project, we aim to enhance the profitability and mitigate the risk of the well-known passive investment - Harry Browne Permanent Portfolio, which comprises 4 components: Stocks, Bonds, Gold, and Cash. It is convinced to thrive over 4 major macroeconomic events: Prosperity, Deflation, Inflation, and Recession; however, we discovered that there was an approximately 15% Max Drawdown during the 2007-2008 Financial Crisis and 8.1% monthly loss in October 2008. After investigating in investors' behaviors, we believe that investing in Forex Market might generate some positive returns during the normal period while yielding crisis alpha during the financial stress, e.g., the Global Financial Crisis in 2008 and COVID-19 Pandemic Crisis this year.

Compared to trading other financial instruments, the forex market has some benefits for us to trade. First of all, Forex is traded 24 hours a day due to its over the counter (OTC) characteristic. Second, it does not require borrowing cost for entering into short position. Moreover, the brokerage will not force our currency pairs in short position to be closed when we could gain profits. Third, it is nearly impossible for any single entity to manipulate the market with many participants all over the world, not to mention its 0 commission, flexible size, low transaction cost, high liquidity, and so on.

2 Preliminary Settings and Methodologies

2.1 Setup

2.1.1 Platform and Programming Language Used

This research was conducted on QuantConnect, an open-source, cloud-based algorithmic trading platform. All the codes used in this project were written in Python programming.

2.1.2 Data Sources and Trading Signals

In this project, since the strategy involves both equity and forex, the following are the data sources respectively:

The equity data used in this project is from a data provider named QuantQuote on Quantconnect platform. There are around 20 thousand tickers since 1998 in the universe, and the data is adjusted for splits and dividends. In the research, we selected 4 Exchange-Traded Funds (ETFs) as a proxy of the components in the Harry Browne Permanent Portfolio, and

For the forex data, it is majorly from the OANDA Brokerage Forex Data on the platform. There are 71 currency pairs since 2004 in the universe, and we selected 18 out of 23 pairs involving United States Dollar (USD), where the 18 pairs are tradable on the Interactive Brokers. Since the equity data is only available in the U.S. market, we decide to set our base currencies into USD; thus, all the following numbers such as Profit and Loss (P&L) are in unit of USD.

The 18 foreign currency pairs are (1) Australian Dollar/U.S. Dollar (AUD/USD), (2) U.S. Dollar/Canadian Dollar (USD/CAD), (3) U.S. Dollar/Swiss Franc (USD/CHF), (4) Euro/U.S. Dollar (EUR/USD), (5) British Pound/U.S. Dollar (GBP/USD), (6) U.S. Dollar/Hong Kong

Dollar (USD/HKD), (7) U.S. Dollar/Japanese Yen (USD/JPY), (8) U.S. Dollar/Danish Krone (USD/DKK), (9) U.S. Dollar/Czech Koruna (USD/CZK), (10) U.S. Dollar/South African Rand (USD/ZAR), (11) U.S. Dollar/Swedish Krona (USD/SEK), (12) U.S. Dollar/Norwegian Krone (USD/NOK), (13) U.S. Dollar/Mexican Peso (USD/MXN), (14) U.S. Dollar/Hungarian Forint (USD/HUF), (15) New Zealand Dollar/U.S. Dollar (NZD/USD), (16) U.S. Dollar/Polish Zloty (USD/PLN), (17) U.S. Dollar/Singapore Dollar (USD/SGD), and (18) U.S. Dollar/Turkish Lira (USD/TRY).

Note that our portfolio is a passive investing strategy that rebalances its position monthly, so the resolution of price data collected for generating signals is from daily close price. The speed of the backtest can be significantly increased compared to the one manipulating the price data in minute or even in tick.

For the trading signals, we did not do any intra-day or day trading; instead, we only executed our trades at 10 am (East Standard Time) on the first trading day of each month. Within our monthly rebalance, we allocate equal amount of capital into each component and strategy.

2.2 Algorithm Framework

2.2.1 Construction of Harry Browne Permanent Portfolio

The permanent portfolio is an investment portfolio by Harry Browne in 1980s (Chen, 2020). In this research, we use the following 4 ETFs for tracking the trend of the components in the portfolio:

1. SPDR S&P 500 ETF Trust (SPY): It is one of the most liquid ETF on U.S. exchanges incepted in 1993. According to the information provided by ETF.com (n.d.), its average dollar volume is around \$36.4 Billion. Additionally, its bid-ask spread is about \$0.01 (0.00%), which is relatively low compared to other S&P 500 Index ETFs.
2. iShares 20+ Year Treasury Bond ETF (TLT): It is a fund incepted in 2002 that approximates the return of the long term U.S. Treasury bonds by tracking the Barclays Capital U.S. 20+ Year Treasury Bond Index. In addition, its average dollar volume is around \$1.7 Billion, and its bid-ask spread is about \$0.01 (0.01%).
3. SPDR Gold Shares (GLD): It is the largest ETF to invest directly in physical gold incepted in 2004. It intended to offer investors a means of participating in the gold bullion market without the necessity of taking physical delivery of gold, and to trade a security on a regulated stock exchange (“SPDR Gold Shares”, n.d.). Its value is determined by LBMA PM Gold Price, so it has a close relationship with Gold spot prices. Moreover, its average dollar volume is around \$2.0 Billion, and its bid-ask spread is about \$0.01 (0.01%). Besides, it is also tradable in Hong Kong market as SPDR Gold Trust (2840.HK).
4. iShares 1-3 Year Treasury Bond ETF (SHY): It represents the “Cash” component in the originally proposed portfolio since it could earn some profits during the normal period while hedging against risk during the recession. It is an ETF incepted in 2002 that tracks ICE U.S. Treasury 1-3 Year Bond Index, a market weighted index of debt issued by the U.S. Treasury with 1-3 years remaining to maturity. Furthermore, its average dollar volume is around \$0.5 Billion, and its bid-ask spread is about \$0.01 (0.01%).

2.2.2 Forex Strategies

In this project, we examine several strategies such as Mean Reversion, Risk Premia, Carry Trade and Momentum, and we finally found that the latter two could reap the profit in the normal time and create a crisis alpha during the financial stress.

For Forex Carry Trade strategy, it is a common practice in foreign exchange market. The strategy simply sells (shorts) the currency pair with lower interest rate and buys (longs) high-interest rate currency pair. Its profit is from the spread of the rates between two or several countries. For simplicity, it is similar to say you borrow the money from countries that require lower rate and invest those money into other countries with higher rate. In this strategy, the parameter to be changed is the weight in the long/short pair.

For the Forex Momentum, it is a trend-following strategy. The strategy buys (longs) assets that perform well historically and sells (shorts) the one performing poorly in the past. Since 252-day momentum is recognized in the community (Rohrbach, Suremann & Osterrieder, 2017; Varadi, 2016), we decided to follow it and find the currency pairs with top strongest 252-momentum to hold. The parameters to be tested are number of pairs with strong momentum to long and whether we should short the pair(s) with top lowest momentum among all currency pairs.

2.2.3 Evaluation Metrics

Before introducing the two Ratios that we used as the measurement in the project, we would like to introduce several important measures: Compound Annual Growth Rate (CAGR), Annualized Volatility (σ), and Max Drawdown (MDD). They are defined in the following:

Notations: Denote N as number of trading days and V_t as the portfolio value at day t where $t \in \{0, 1, \dots, N\}$.

1. CAGR: It is an annualized rate of return for an investment to grow in T year(s). We assume that there are 252 trading days per year, so we can simply divide the number of trading days by 252 to get T .

$$T = \frac{N}{252}$$
$$CAGR = \left(\frac{V_N}{V_0}\right)^T - 1$$

2. σ : Volatility is a statistical measure of the dispersion of returns, and it is measured as the standard deviation between returns during a period. Usually, we calculated the volatility based on the daily return; thus, we have to multiply the result by square root of 252 to get the Annualized Volatility. The formula is defined as follows:

$$\sigma = \frac{\sum_{i=1}^N (R_t - \bar{R})}{N - 1} \cdot \sqrt{252},$$

where R_t is the **daily** realized return on day t and \bar{R} is the average of all realized returns in N days.

3. MDD: Drawdown (DD) is the measure of the decline from a historical peak to the current level, and the Max Drawdown (MDD) on day t is the maximum observed loss from a peak to a trough of a portfolio from day 0 to day t . They are defined by:

$$DD_t = \frac{V_t}{\max\{V_0, \dots, V_t\}} - 1, \text{ where } t \in \{0, \dots, N\}$$



Figure 1: Equity Curve Example

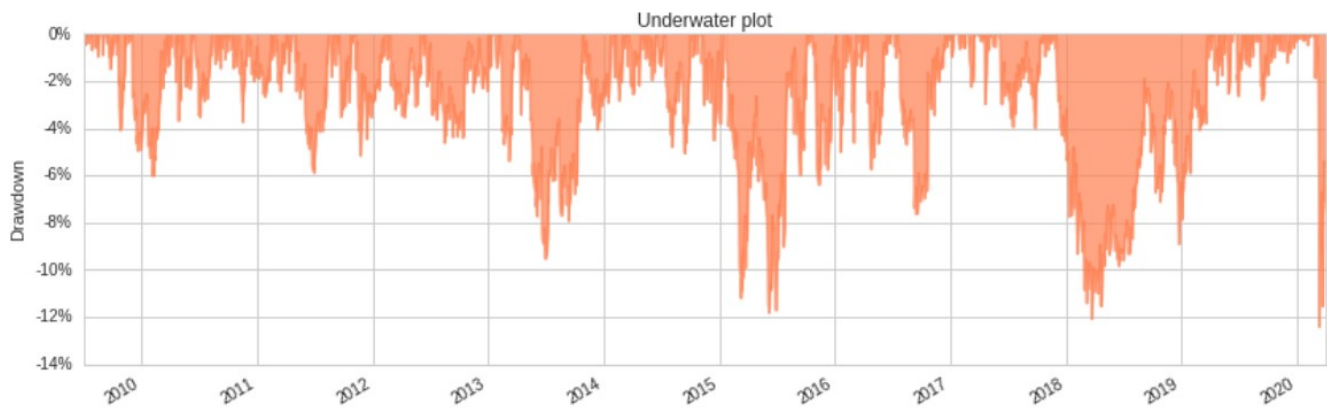


Figure 2: Illustration of Drawdown Corresponding to the Equity Curve Example

$$MDD_t = \min\{DD_0, \dots, DD_t\}, \text{ where } t \in \{0, \dots, N\}$$

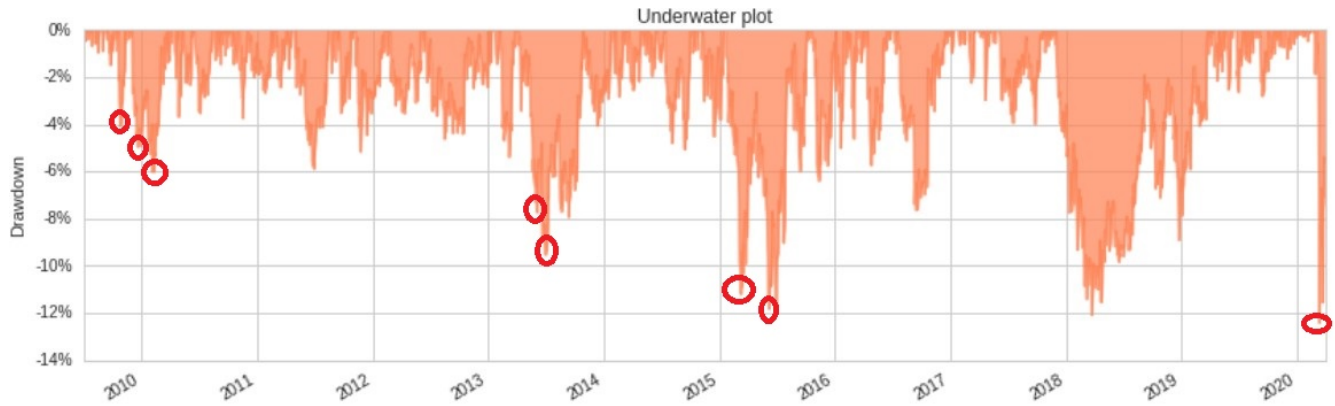


Figure 3: Drawdown Diagram Example

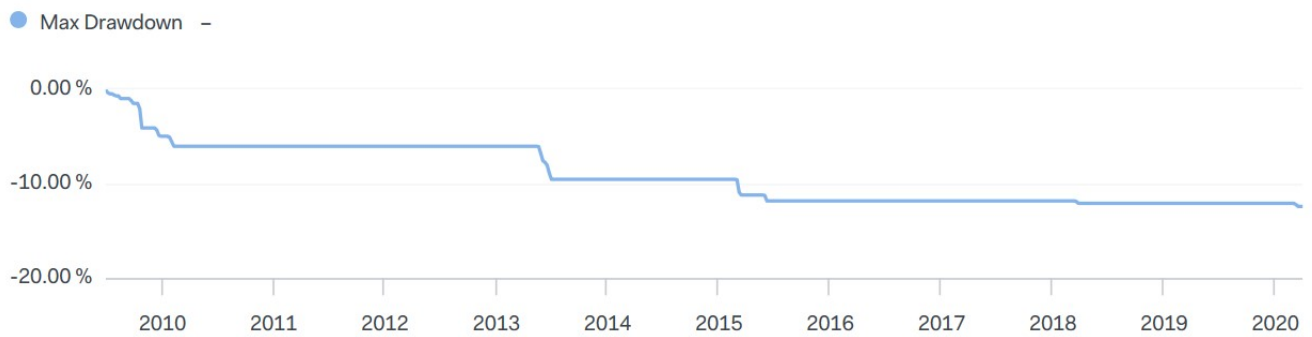


Figure 4: Illustration of Max Drawdown Corresponding to the Drawdown Diagram Example

As marked in the Drawdown Diagram Example, it is obvious to note that the Max Drawdown reaches to a new level once a new valley is achieved.

In the project, we aim to find a portfolio that is profitable with acceptable risk. Thus, we evaluated the performance of a portfolio by profitability and some risk-adjusted measures such as **Sharpe Ratio** and **MAR Ratio**.

For the Sharpe Ratio, we used the average of 6-Month rolling Sharpe Ratio instead of the Sharpe Ratio over the whole trading period. The definition of Sharpe Ratio is:

$$\text{Sharpe Ratio} = \frac{CAGR - R_f}{\sigma},$$

where R_f is the annual risk-free rate.

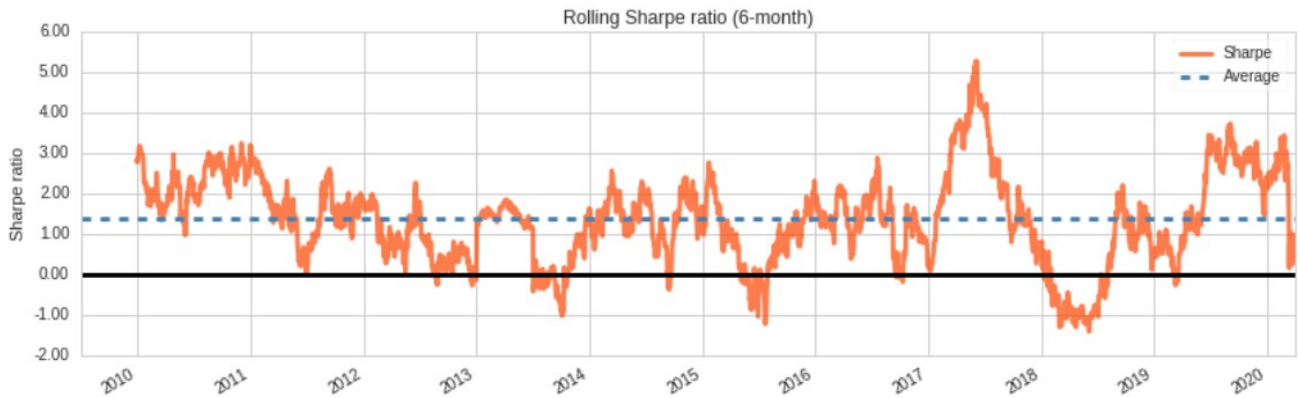


Figure 5: Illustration of 6-Month Rolling Sharpe Ratio and the Ratio for the Portfolio

For the MAR Ratio, it is a measure that describe the frequency of the portfolio to recover from the most significant drawdown. For example, if the MAR ratio is 0.5, it means that the annual growth rate is 0.5 times of your Max Drawdown. That is, it might require 2 years for the portfolio to recover averagely. It is defined as follows:

$$\text{MAR Ratio} = \frac{CAGR}{MDD}$$

3 Backtesting Results

During the backtest, we set the original capital as \$10 Million USD to ensure that the liquidity issue has not been overlooked in the test. Furthermore, the testing period of the backtesting results is from 1st January 2005 to 30th April 2020 for the following reasons:

1. The forex data from OANDA Brokerage Forex Data is available since 2004 and the Forex Momentum strategy requires 1-year warm-up period after the data is available for generating the signal from 252-day momentum.
2. The gold ETF (GLD) in the Permanent Portfolio is incepted after the mid-November in 2004, and other 3 components are incepted earlier than GLD.
3. Since we would like to set our currencies universe as big as possible to prevent losing the profitable opportunities from some currencies, several currency pairs whose data is available since February 2007, such as Turkish Lira (TRY), are included into the strategies since 2007. Be reminded that we did not select Onshore Chinese Yuan (CNY) into our universe even though its price data is also available from February 2007.
4. As the economy of China is currently ranked the second in the world, keeping Chinese Renminbi (CNY for onshore/CNH for offshore) in our universe to be a good counterpart of USD in our forex strategies sounds logical. However, we decided to delete it from our universe for two reasons: First, the onshore Chinese Yuan (CNY) is not tradable outside mainland China and the exchange rate is controlled by the central bank, so the final backtest result would rather be theoretical than a practical investment strategy if we included it into our universe as a possible asset to hold. This contradicts to our goal that we wish to propose an idea to enhance Permanent Portfolio in practice. Second, despite the fact that the exchange rate of the offshore Chinese Yuan (CNH) is freely determined by the market, its data is only available since August 2015, which might not be a suitable choice to be included.
5. We believe that testing whether the portfolio can survive during crises is an important part of algo trading. Thus, we deliberately include Global Financial Crisis in 2007-2008 and 2020 Stock Crash from Mid-February to Mid-March in 2020 in our testing period.

3.1 Forex Carry Trade (FCT)

In this strategy, we extracted the central bank interest rate from Quandl. For the trading universe, there are only 9 currencies whose rate is available on Quandl and we finally picked 7 out of these 9 currencies since India Rupee (INR) and Chinese Renminbi (CNY) are not in our tradable universe. We only rebalanced monthly to adjust our positions provided that the interest rate fluctuations are expected to be rare within a month and it will be costly for us to rebalance our position with higher frequency.

3.1.1 Important terminologies

Before explaining how we decided the weight and number of pairs to long and short, we would like to introduce several terms for a better understanding of this kind of long-short strategy. In this strategy, we can divide our positions into three parts: (1) U.S. Dollar, (2) Long position in the currency, and (3) Short position in the currency. We denote their values as Cash, Value of Long Position (VLP) and Value of Short Position (VSP) respectively. Note that VSP usually is a negative number. Then we define Total Equity (TE), Dollar Net Exposure (DNE), Gross Exposure (GE), Percent Net Exposure (%NE), and Percent Gross Exposure (%GE) in the following:

$$\begin{aligned}TE &= Cash + VLP - |VSP| \\DNE &= VLP - |VSP| \\GE &= VLP + |VSP| \\%NE &= \frac{DNE}{TE} \\%GE &= \frac{GE}{TE}\end{aligned}$$

3.1.2 Weight in the currency pairs

Taking into account that changing the weight in the currency pairs is similar to leverage, in this section, we only compare three cases : %GE = 100%, %GE = 150%, and %GE = 200%. First of all, it makes no sense for us to set %GE < 100% under the stipulation that the strategy itself would be incorporated into our portfolio as a component and there would be some idle cash if we did not set the %GE at least 100%. Moreover, we believe that it is not proper to have more than 100% exposure in either the long or short position, i.e. %GE ≤ 200%, even though the Dollar Net Exposure (DNE) is 0 for our Carry Trade. Finally, besides selecting the cases that %GE = 100% and %GE = 200%, we also select %GE = 150% as a midpoint in between of 100% and 200%.

Case I: 100% Gross Exposure

Cumulative Returns

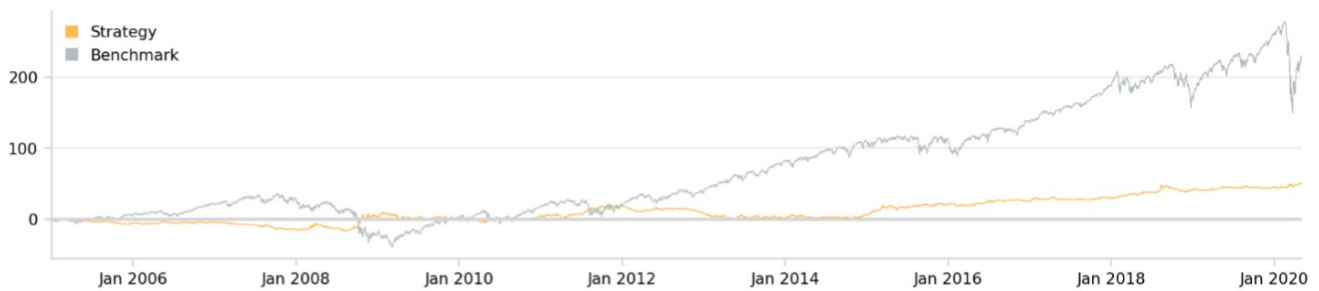


Figure 6: Equity Curve for FCT with 100% GE

Annual Returns

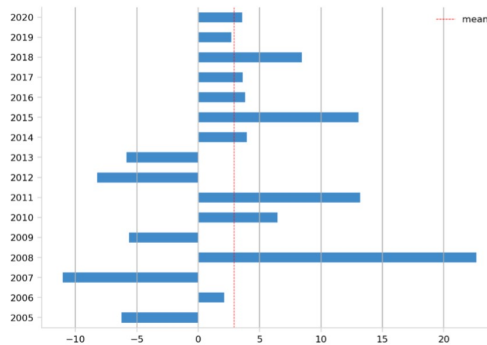


Figure 7: Annual Return Diagram for FCT with 100% GE

We can observe that the payoff of the FCT strategy with GE = 100% is much less attractive than investing in SPY alone from the equity curve. Nevertheless, it is easy to point out a significant growth of 22% in 2008, and it will be a beneficial component for us to survive during the recessions. Its annual return is merely 2.69% while the Max Drawdown is 16.9%. Overall, its profitability is not desirable and will harm our profits considerably with its low return.

Case II: 150% Gross Exposure

Cumulative Returns

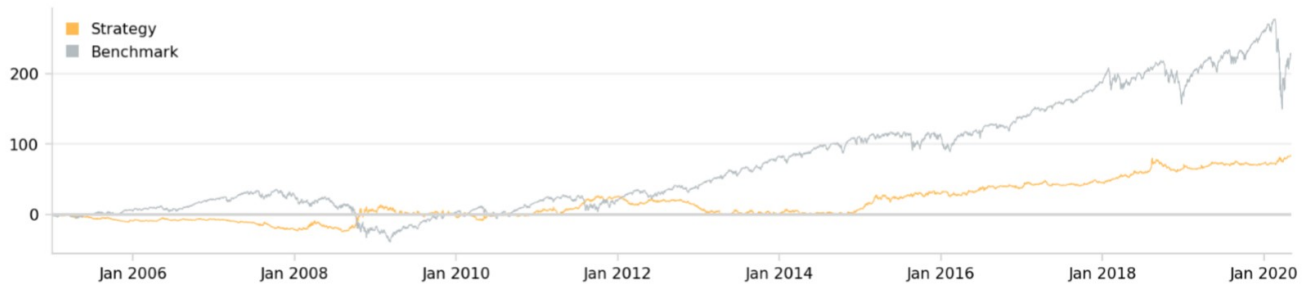


Figure 8: Equity Curve for FCT with 150% GE

Annual Returns

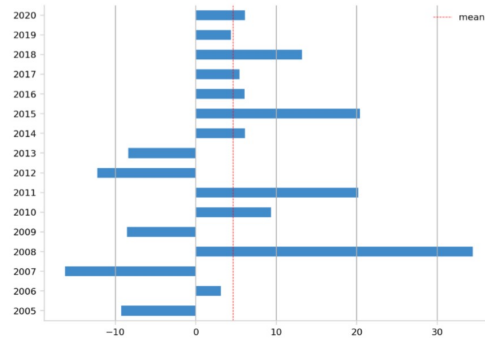


Figure 9: Annual Return Diagram for FCT with 150% GE

Similar to the one with 100% GE, the strategy with 150% GE is less attractive than investing in SPY. It produced an around 4% annual return over 16 years and more than 30% annual return in 2008. Yet, it is not the optimal one for us to consider it as the final strategy since our goal is to find a way to hedge the risk while not to sacrifice too much.

Case III: 200% Gross Exposure

Cumulative Returns

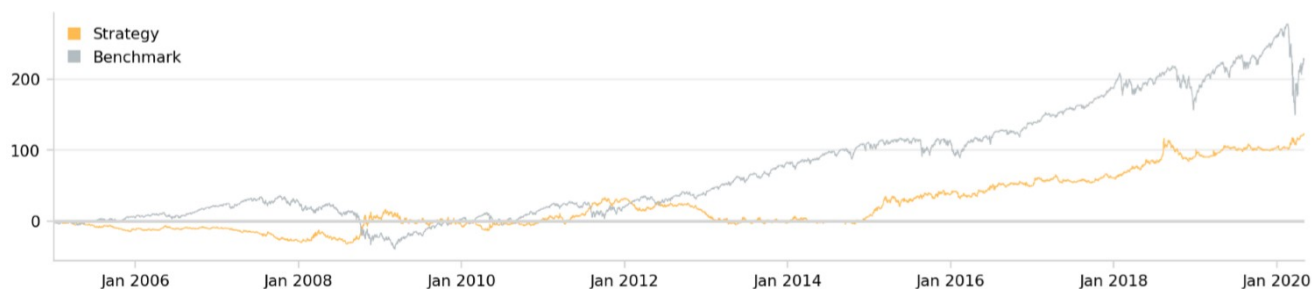


Figure 10: Equity Curve for FCT with 200% GE

Annual Returns

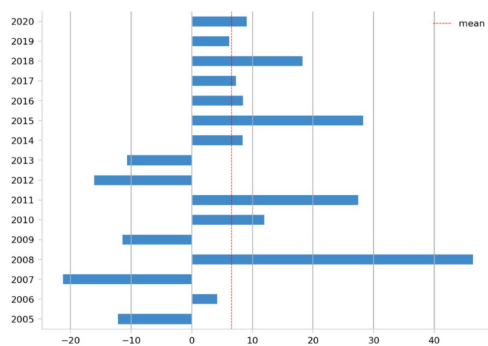


Figure 11: Annual Return Diagram for FCT with 200% GE

Compared to two cases discussed in this section, it is more desirable for us to have 200% GE as the final strategy for two reasons. First, the annual returns from both cases with 100% and 150% GE are not sufficient to maintain the profitability of the original Permanent Portfolio, which the annual return of Permanent Portfolio is above 7%. Second, we require the strategy to have a high crisis alpha for compensating the possible losses in the Permanent Portfolio during the crises. It will be acceptable for us to invest a small portion of our capital to the strategy with a 32.4% Max Drawdown while having an annual return of 45% in 2008 and an annualized return of 27% in 2020.

After making comparisons for three parameters in this strategy, we finally obtained an optimal¹ Forex Carry Trade strategy with annual return of 5.36%, Sharpe Ratio 0.346, and MAR Ratio 0.165 with %GE = 200%. Although these numbers alone are not attractive, we are confident that its crisis alphas and long-term positive profitability can help us enhance the Permanent Portfolio as a hedge during the crisis. Next, we continue our evaluation on another strategy - Forex Momentum.

¹After some investigations, we explore that the performance can be further improved if we long/short more pairs. For details, please refer to Appendix A

3.2 Forex Momentum (MOM)

In the strategy, we investigate the best parameters that can effectively reap profits while create crisis alphas to hedge against the downside of the original Permanent Portfolio. We consider the strength of 252-day momentum as the signal for us to decide which currency pair to trade. Recall that the parameters to be researched on are number of currencies to long and whether we should short currencies with low momentum.

3.2.1 Number of currencies with strong momentum to long

In light of the fact that there are 18 currencies in our forex universe, we decided to examine the performance of longing 1 to 9 currencies. The following is the summary table for 9 long-only cases:

Table 1: Summary of All 9 Long-Only Strategies

Rank	#_To_Long	CAGR	MDD	Sharpe	Sharpe_Rank	MAR	MAR_Rank	Total_Rank
1	1	3.58%	21.50%	0.297	2	0.167	1	3
2	2	4.34%	35.60%	0.363	1	0.122	2	3
3	3	2.75%	48.10%	0.214	4	0.057	3	7
4	9	3.34%	77.30%	0.249	3	0.043	4	7
5	7	2.30%	72.50%	0.210	5	0.032	5	10
6	4	1.11%	72.60%	0.190	6	0.015	7	13
7	6	1.23%	63.70%	0.167	8	0.019	6	14
8	8	0.93%	77.50%	0.185	7	0.012	8	15
9	5	-0.62%	79.60%	0.143	9	-0.008	9	18

In the above table, we found that the strategies that long either 1 or 2 currencies with strongest momentum are the front runners among these 9 choices. Other than these two strategies, there are no strategies that can provide us a Sharpe Ratio of higher than 0.25 nor more than 0.1 MAR Ratio. Further, we notice that longing 2 pairs is the best in terms of Sharpe Ratio while longing 1 pair is the best for MAR Ratio. Next, we will discuss their profitability and equity curves in details.

Case I: Long the currency with the strongest momentum

Cumulative Returns



Figure 12: Equity Curve for MOM with Longing 1 Currency

Annual Returns

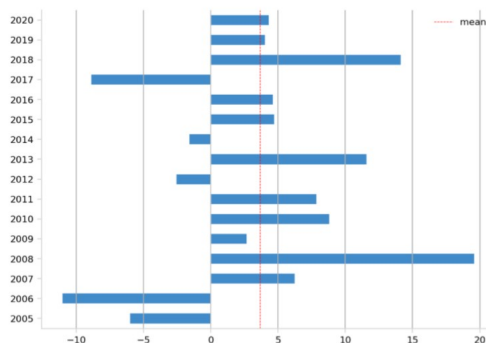


Figure 13: Annual Return Diagram for MOM with Longing 1 Currency

From the images, we note that its equity curve is not smooth due to a 9% loss in 2017. On top of that, it has some desirable crisis alphas, e.g., about 20% growth in 2008 and positive return in the first 4 months of this year. However, its overall return of 3.58% is merely a half of the original Permanent Portfolio and we may wish to have a strategy with a better profitability. Then, we consider the strategy longing 2 pairs.

Case II: Long the currencies with top 2 strongest momentum

Cumulative Returns



Figure 14: Equity Curve for MOM with Longing 2 Currencies

Annual Returns

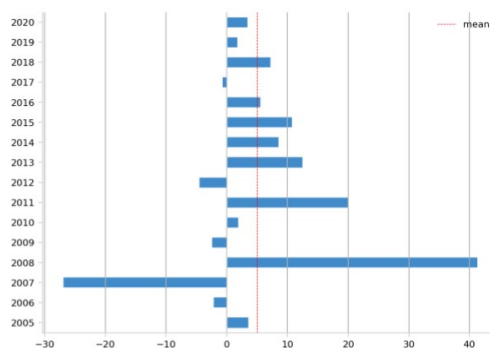


Figure 15: Annual Return Diagram for MOM with Longing 2 Currencies

As shown in the images, it has a tremendous return of over 40% in 2008 and especially a 27.3% monthly return in the worst month of the original Permanent Portfolio. Apart from having a higher crisis alpha in 2008, it also possessed a higher long-term profitability of 4.34%. Finally, we decided to **long the currencies with top 2 strongest momentum** for the following reasons:

1. It has a higher annual growth rate of 4.34% compared to the one of longing 1 currency. As mentioned previously, reaping sufficient profit is also a crucial criterion for us to select a proper component in the portfolio.
2. It has higher crisis alphas in 2008 and 2020 than its counterpart, which can hedge against the downside of the original Permanent Portfolio.

3.2.2 Possibility of short currencies with top lowest momentum

Next, we explore whether shorting the currencies with low momentum can boost the profits. For simplicity, we consider 9 cases where we long and short equal number of currencies. Similarly, the following is the summary table for 9 long-short cases:

Table 2: Summary of All 9 Long-Short Strategies

Rank	#_To_Long/Short	CAGR	MDD	Sharpe	Sharpe_Rank	MAR	MAR_Rank	Total_Rank
1	1	2.01%	34.40%	0.181	2	0.058	1	3
2	2	1.32%	67.20%	0.182	1	0.020	2	3
3	7	-1.49%	80.90%	0.162	3	-0.018	3	6
4	6	-2.83%	84.10%	0.133	5	-0.034	4	9
5	9	-4.08%	90.20%	0.148	4	-0.045	5	9
6	3	-4.02%	84.00%	0.079	9	-0.048	6	15
7	8	-5.69%	92.60%	0.103	8	-0.061	7	15
8	5	-6.63%	91.40%	0.109	7	-0.072	8	15
9	4	-7.01%	94.00%	0.125	6	-0.075	9	15

Surprisingly, 7 out of 9 choices made us suffer from loss over the past 16 years and returns of the remaining 2 choices are not satisfactory compared to the strategy that only longs 2 currency pairs with the highest momentum. Therefore, we decide **not to short** the currency pair(s) with weak momentum.

3.3 Evaluation of the weight for 4 components and 2 strategies

After selecting proper parameters for 2 strategies above, we would like to investigate on how we could optimally allocate the capital to each of the components or strategies. We consider 63 cases where we only decide whether we would like to allocate the capital into this component or strategy. The following is the summary table for the top 10 portfolios ranked by the sum of the rank in Sharpe Ratio and MAR ratio².

Table 3: Summary of Top 10 Portfolios

Rank	SPY	TLT	GLD	SHY	FCT	MOM	CAGR	MDD	Sharpe	Sharpe_Rank	MAR	MAR_Rank	Total_Rank
1	0%	0%	0%	100%	0%	0%	2.18%	2.20%	1.354	1	0.989	1	2
2	17%	17%	17%	17%	17%	17%	6.43%	7.40%	1.002	4	0.869	2	6
3	20%	20%	20%	20%	0%	20%	6.54%	8.20%	0.982	5	0.797	4	9
4	20%	20%	20%	0%	20%	20%	7.29%	8.80%	0.965	7	0.829	3	10
5	25%	25%	0%	25%	25%	0%	6.42%	9.40%	1.009	3	0.683	10	13
6	25%	25%	0%	25%	0%	25%	5.62%	7.30%	0.951	9	0.770	5	14
7	20%	20%	20%	20%	20%	0%	7.16%	11.00%	1.014	2	0.651	12	14
8	20%	20%	0%	20%	20%	20%	5.67%	7.50%	0.926	11	0.756	6	17
9	25%	25%	25%	0%	0%	25%	7.63%	10.70%	0.933	10	0.713	8	18
10	25%	25%	25%	0%	25%	0%	8.42%	13.60%	0.975	6	0.619	15	21

^a If a portfolio ties with another one in Total Rank, the final rank is determined by the MAR_Rank given that the Sharpe Ratios are all above 0.9 for top 10 portfolios.

As the table above shown, it is surprised that the original Permanent Portfolio is not on the top 10 with the criteria given its MAR ratio is ranked the 22th among all 63 portfolios. However, it is notable that all of them have less than 10.70% Max Drawdown, more than 0.877 Sharpe Ratio and at least 0.683 MAR Ratio over 16-year backtesting period, which the Sharpe Ratio for the well-known investor Warren Buffett is around 0.8 (Frazzini, Kabiller & Pedersen, 2018). Especially, the portfolio that allocates all the capital in short-term U.S. Treasury Bills (SHY) gave us the highest Sharpe Ratio of 1.354 and the highest MAR ratio of 0.989. Nevertheless, it seems not desirable for us to receive around 2.2% gain annually in return since holding 100% in SHY is similar to saving your capital into the bank deposit and earn the time value of money. After all, it is well-known in finance that we will only earn profit through compensation for bearing risk. Next, we would analyze the portfolio with 100% capital in SHY and the one with all components and strategies equally weighted in details.

²For the complete list of 63 portfolios, please refer to Appendix B

Cumulative Returns

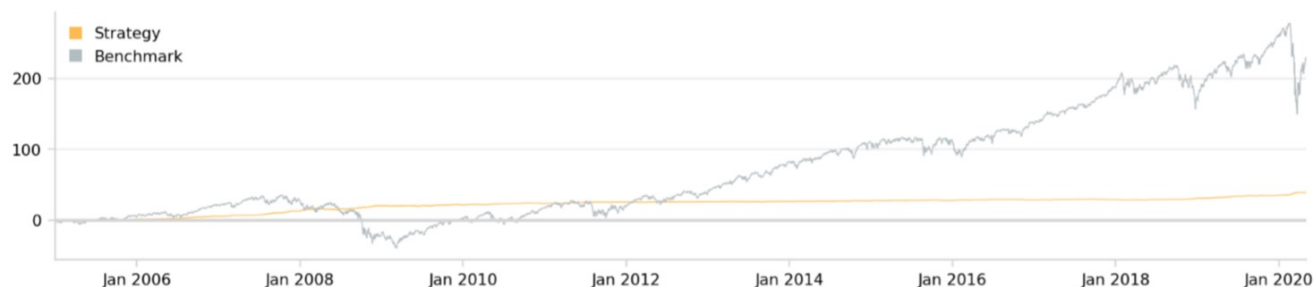


Figure 16: Equity Curve of 100% in SHY Portfolio from Jan. 2005 to Apr. 2020

Annual Returns

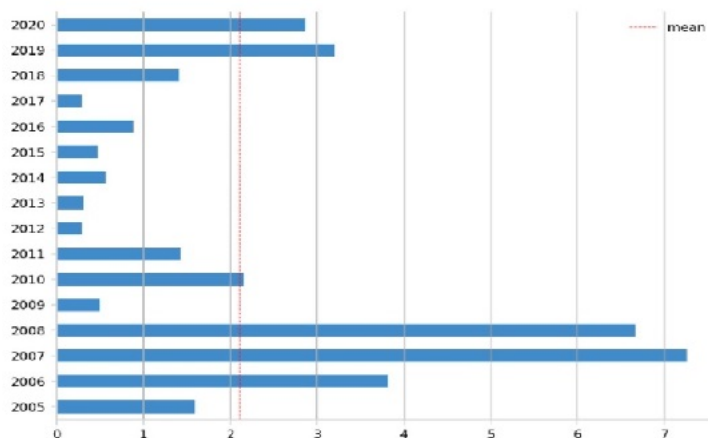


Figure 17: Annual Return Diagram of 100% in SHY Portfolio from Jan. 2005 to Apr. 2020

As the above figures showed, its annual returns are lower than 1% during bullish market in the 2010s. The current level of the yield rate of U.S. short-term Treasury bills is 0.17%³ (“U.S. Department of Treasury”, n.d.), and it is hard to imagine that the yield rate could keep dropping from the current level to the negative level for a long time. Although the yield on short-term Treasury bills has dropped to negative 0.053% in March (Cox, 2020), it is nearly impossible for the U.S. Treasury Bills and Bonds, the asset class that global investors allocate their money in, to have the negative rates for a long time. Thus, it is almost sure that the yield rate of the Short-Term Bills will climb to a higher level so that the price of SHY will drop and the profit of holding SHY will be significantly affected accordingly. We can conclude that it is still highly possible for the investors of SHY to receive 1% annual returns or even less in the future given that the bond price is inversely correlated to its yield rate, which is known as risk-free rate for investors. In conclusion, it is absolutely not a good idea for investors to invest all their money in SHY.

³As of 26th May, 2020

Then, we consider the portfolio with equal weights in all 4 Permanent Portfolio components and 2 forex strategies. It generated 6.43% of CAGR while leading to only 7.40% of Max Drawdown. Moreover, its Sharpe Ratio is 1.002 and MAR Ratio is 0.869, which is ranked the 4th and 2nd among all the 63 portfolios respectively.

Cumulative Returns



Figure 18: Equity Curve of the Equal Weighted Portfolio from Jan. 2005 to Apr. 2020

Annual Returns

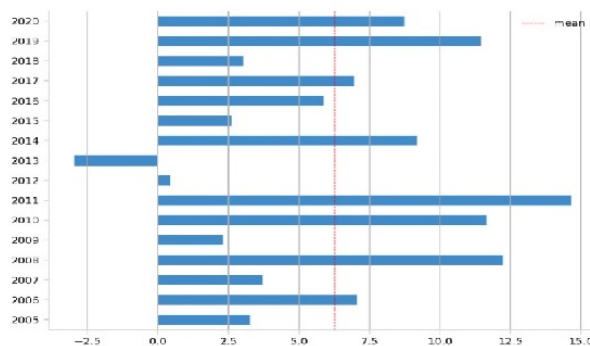


Figure 19: Annual Return Diagram of the Equal Weighted Portfolio from Jan. 2005 to Apr. 2020

As shown in the above figures, the portfolio has a similar payoff to the one that buys and holds the SPY in February 2020, the trough of the current crisis, while the portfolio has a much stable and less volatile equity curve. Moreover, there is only one negative return in a year over 16-year trading period, which the annual loss in 2013 is merely 3%. Surprisingly, the portfolio has significant crisis alphas in 2008 and 2020. In 2008, it earned around 12% annually while the SPY dropped 40% at the same time. In 2020, it already generated a 9% return in the first 4 months while the SPY is leading to a 10% loss meanwhile.

We believe that this portfolio achieves our goal as an enhanced Permanent Portfolio that increases MAR Ratio by 73%⁴. For those investors who are not satisfied with the CAGR of 6.43%, we suggest they lever up to the level they are satisfied with. Subsequently, we would like to justify the profitability of the portfolio through a one-month mock trading.

⁴For the complete information of the optimal portfolio, please refer to Appendix C

4 Execution: 1-Month Paper Trading via the Interactive Brokers

After obtaining the best result from the backtest, we are interested in knowing whether the past performance can be replicated in the real-life trading. Moreover, we would like to examine whether the effect of latency from manual trading and borrowing interest for the foreign currencies makes our strategies not profitable. Therefore, we decided to execute our trades on Interactive Brokers Paper Trading Account in May 2020. We executed our trades at 10 pm Hong Kong Time (HKT), which is 10 am EST, on 1st May 2020 after the signals for MOM and FCT are generated from QuantConnect.

The signals generated from the backtest result are in the following:

1. MOM: Long USD/MXN and USD/HUF with the weight of 1/12 respectively.
2. FCT: Short EUR/USD and Long USD/CAD with the weight of 1/6 respectively.
3. Permanent Portfolio: Equally allocate the remaining 2/3 of the total capital into SPY, TLT, GLD, and SHY.

Note that we used IBAlgo Market Buy/Sell for the order of equities. For forex, we adopted IBAlgo TWAP Market Order for the order.

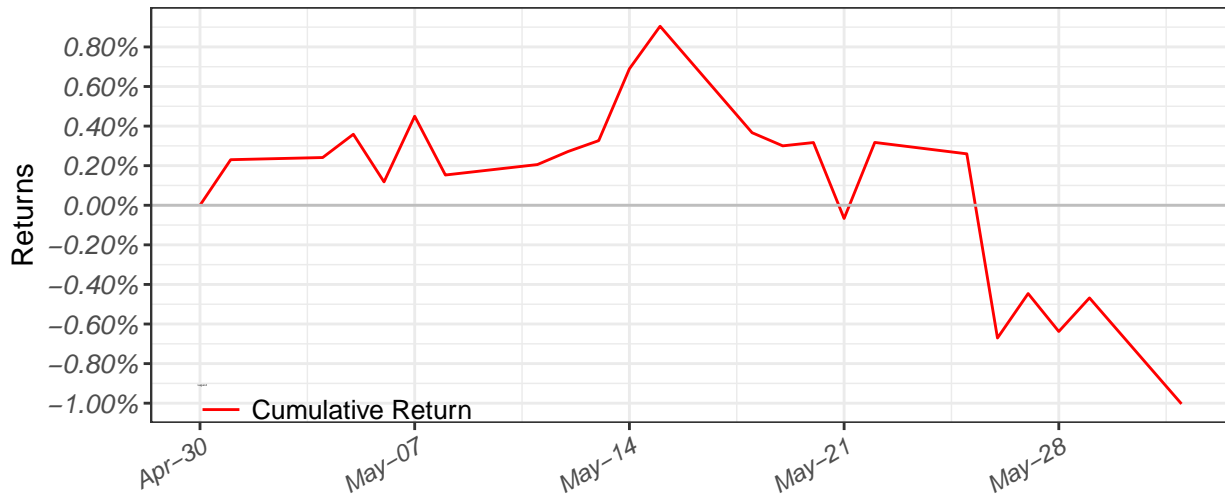
4.1 Performance Analysis

The following is the summary table, equity curve, daily return, Drawdown, and Max Drawdown of the whole portfolio.

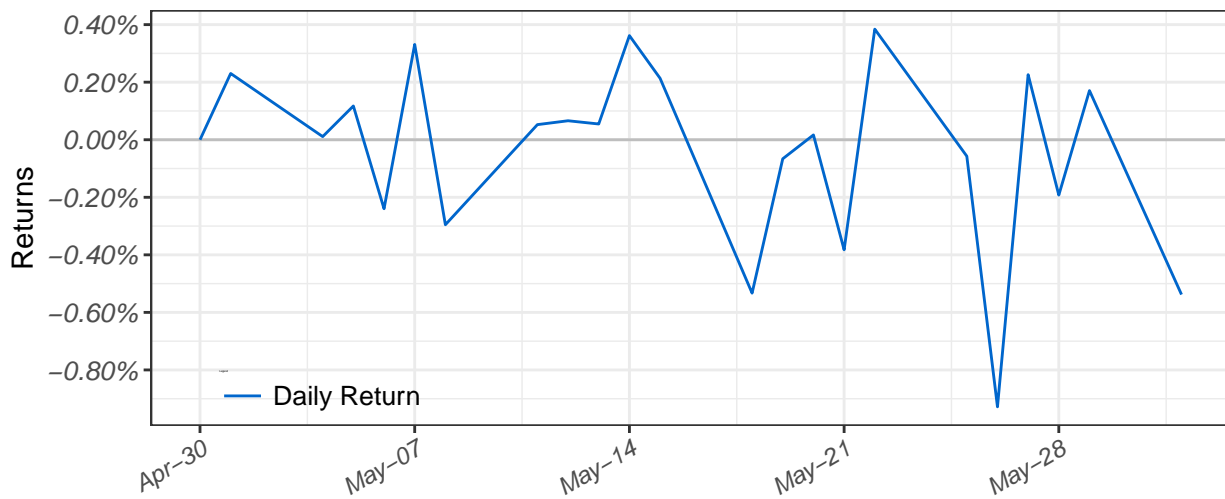
Table 4: Summary Table of the Portfolio in May

CAGR	Sharpe_Ratio	MAR_Ratio
-11.40%	-2.162	-6.029

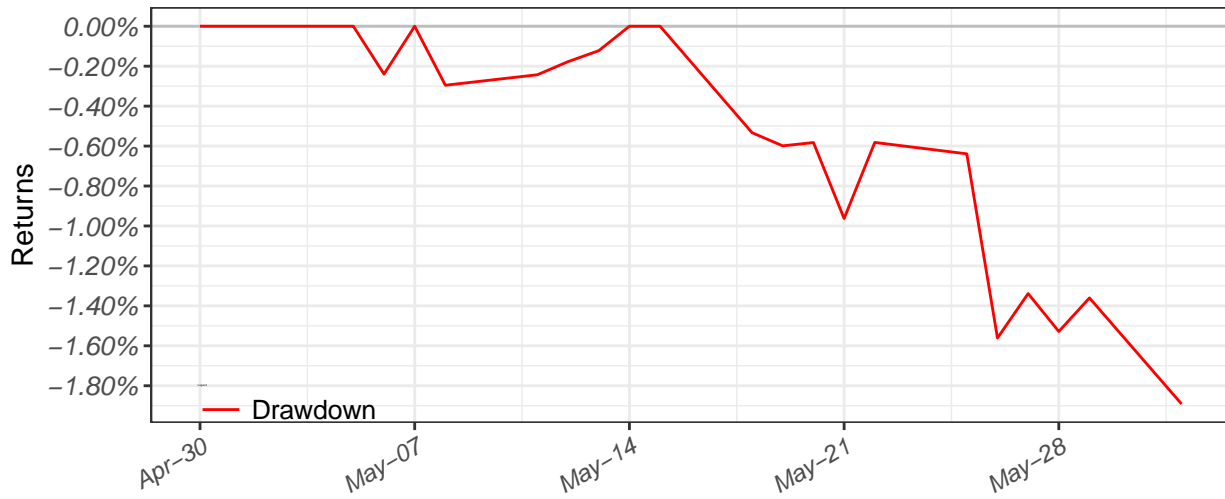
Equity Curve of the Portfolio in May



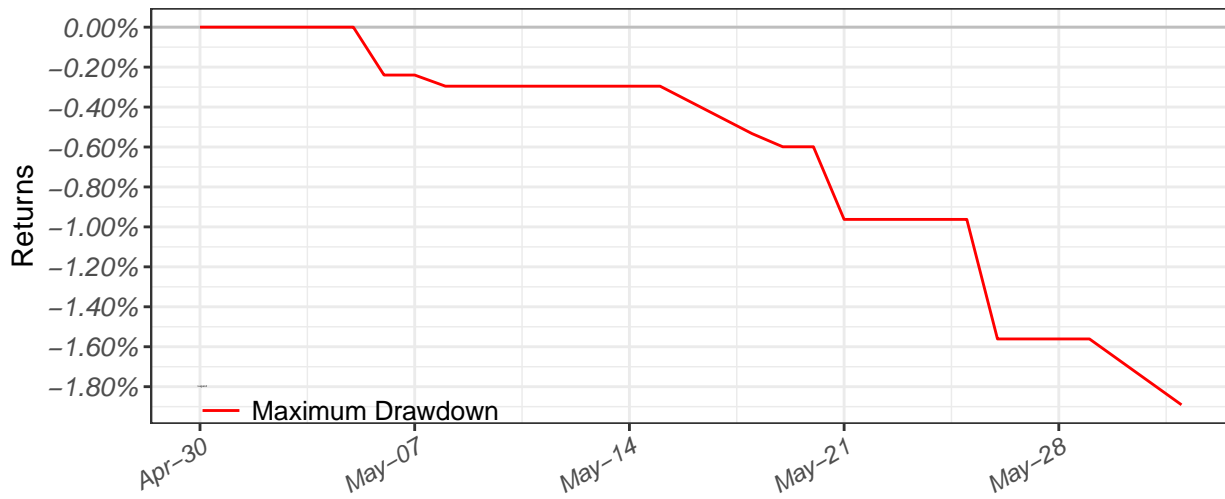
Daily Return Diagram of the Portfolio in May



Drawdown Diagram of the Portfolio in May



Max Drawdown Diagram of the Portfolio in May



4.2 Breakdown for each component and strategy

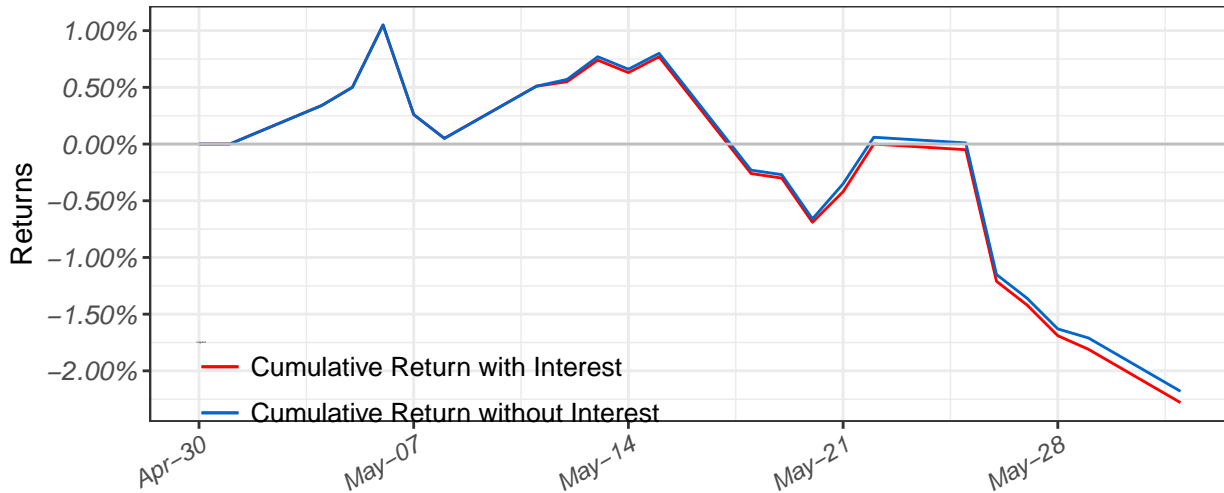
Similar to what we did for the overall portfolio, we provided the summary table, equity curve, daily return, Drawdown, and Max Drawdown for each component then analyzed it in details. For the breakdown, we split the whole portfolio into 7 parts for further analyses:

4.2.1 The pair in FCT

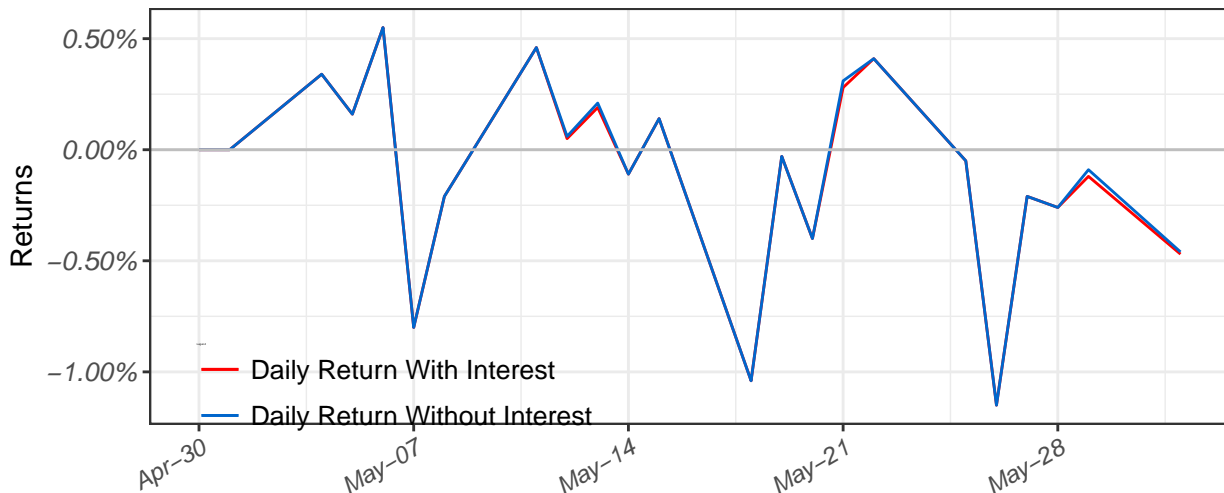
Table 5: Summary Table of FCT in May

Type	CAGR	Sharpe_Ratio	MAR_Ratio
With_Interest	-24.18%	-3.352	-7.337
Without_Interest	-23.24%	-3.210	-7.271

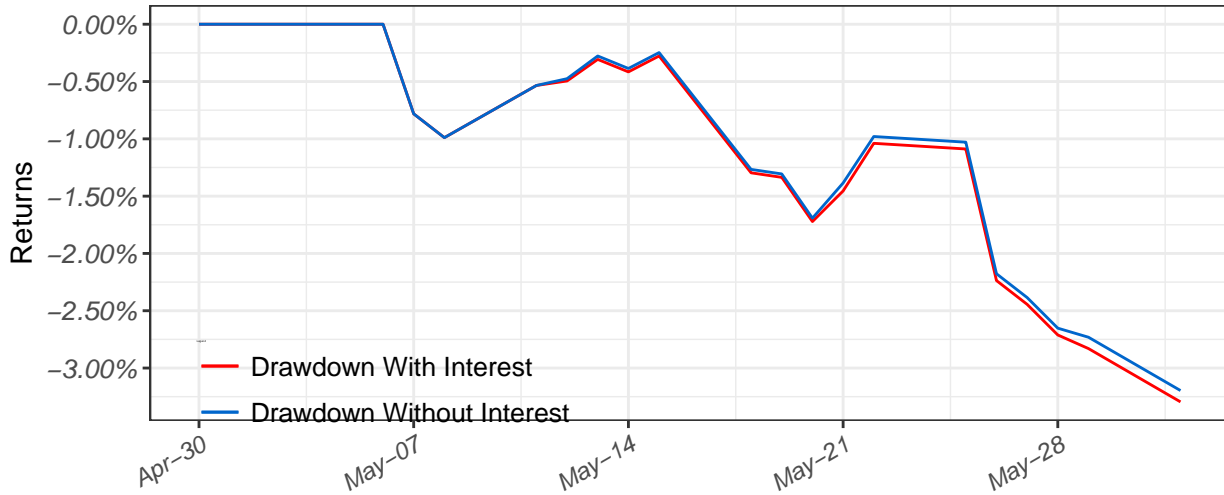
Equity Curve of Forex Carry Trade in May



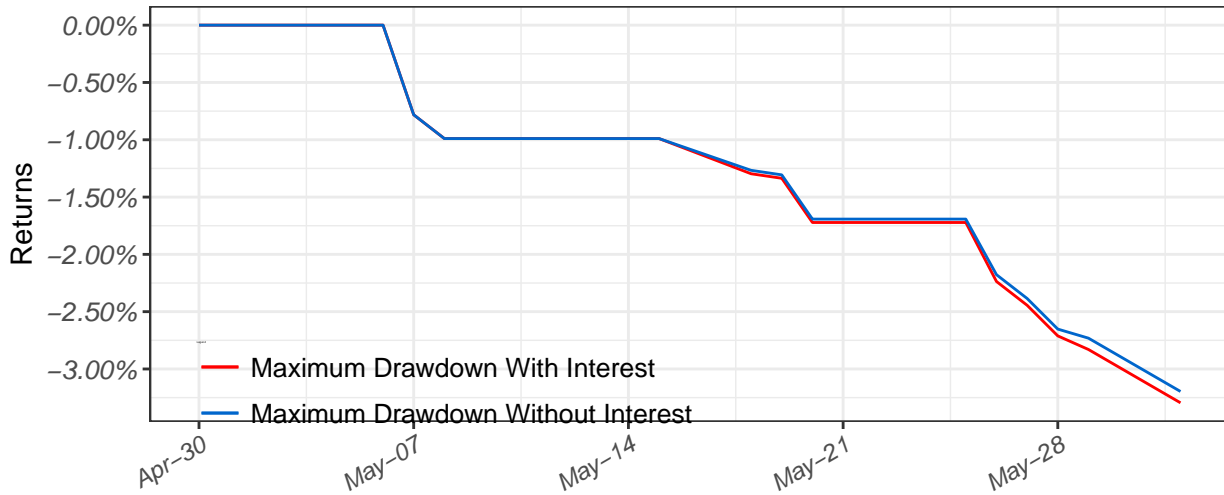
Daily Return Diagram of Forex Carry Trade in May



Drawdown Diagram of Forex Carry Trade in May



Max Drawdown Diagram of Forex Carry Trade in May

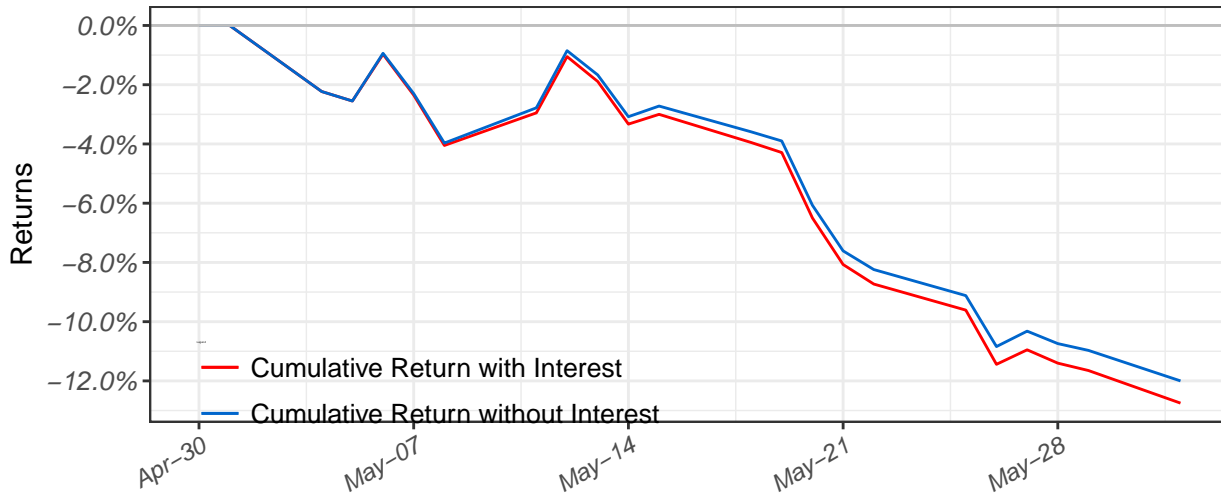


4.2.2 USD/MXN in MOM

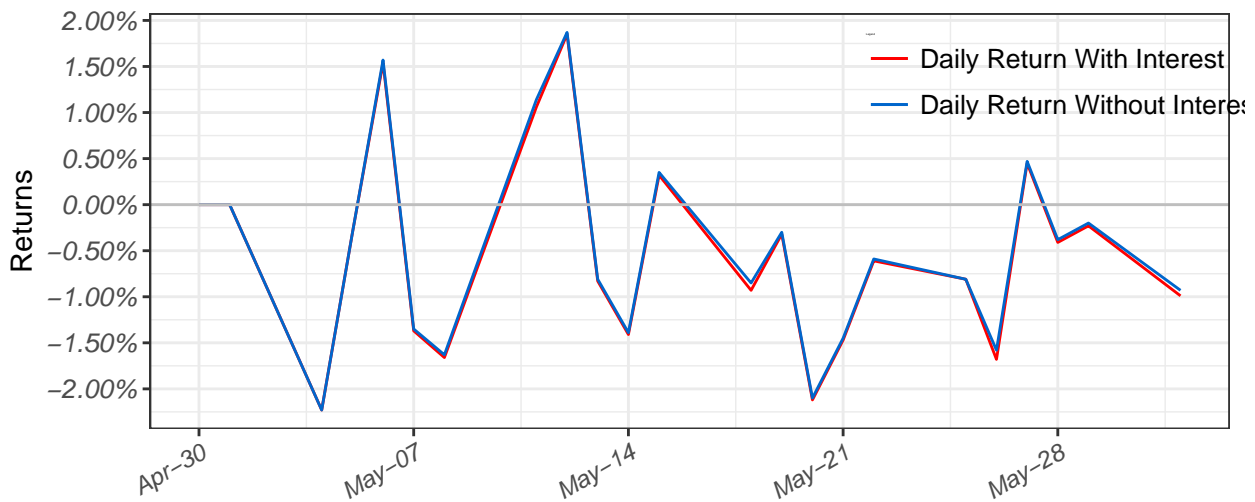
Table 6: Summary Table of USD/MXN in May

Type	CAGR	Sharpe_Ratio	MAR_Ratio
With_Interest	-80.54%	-4.599	-6.317
Without_Interest	-78.43%	-4.475	-6.536

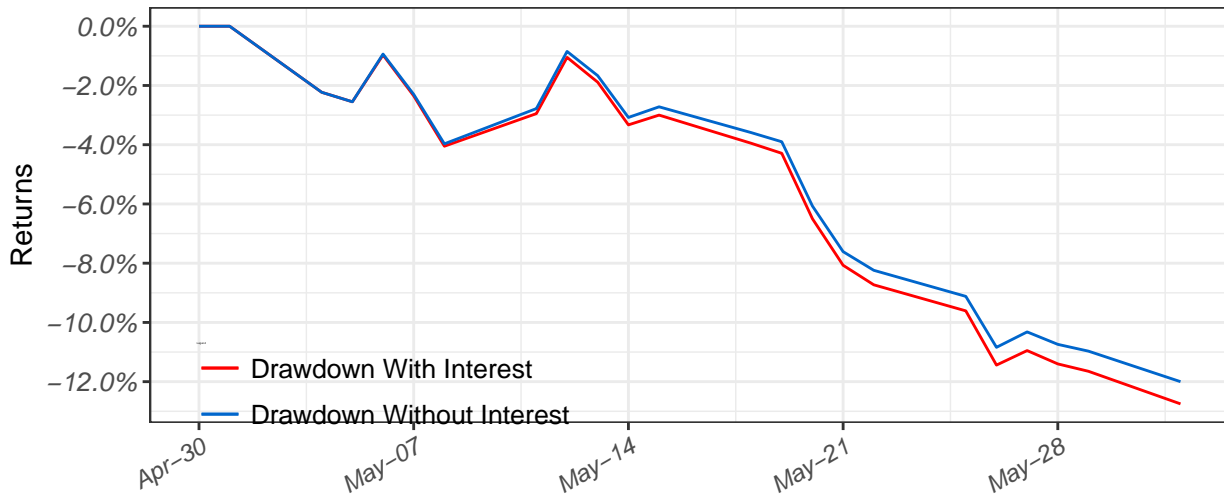
Equity Curve of USD/MXN in May



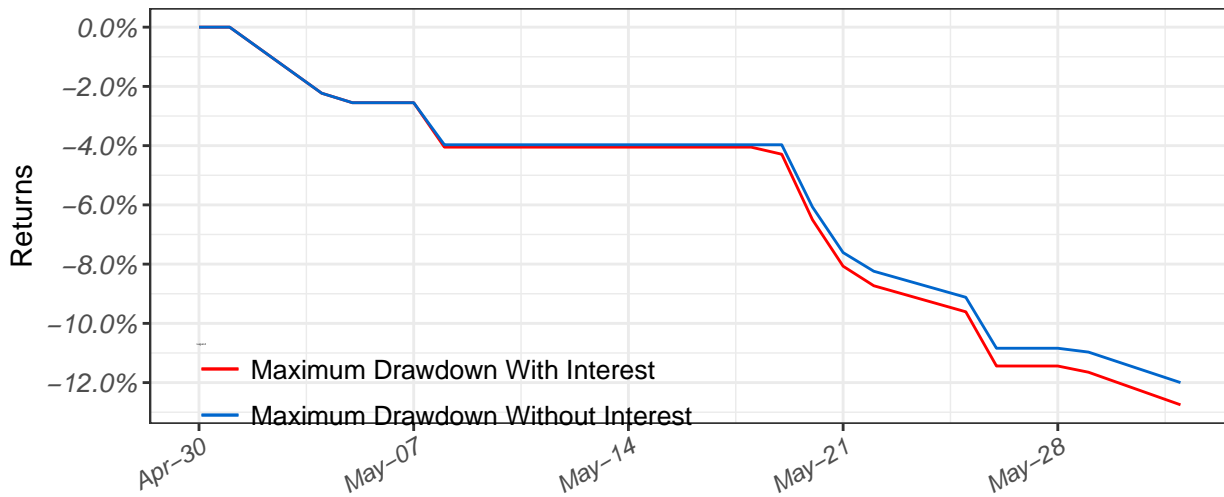
Daily Return Diagram of USD/MXN in May



Drawdown Diagram of USD/MXN in May



Max Drawdown Diagram of USD/MXN in May

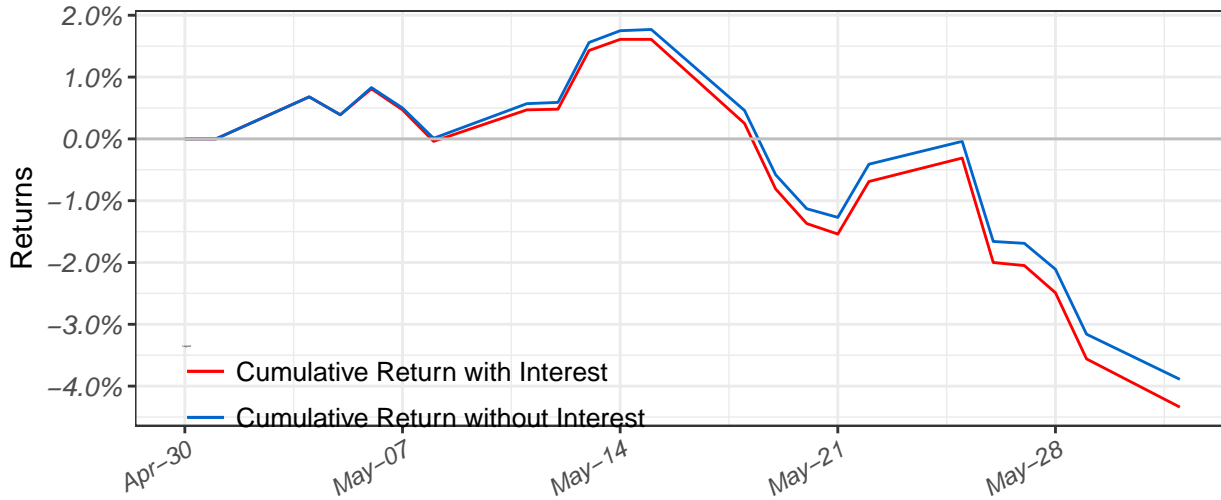


4.2.3 USD/HUF in MOM

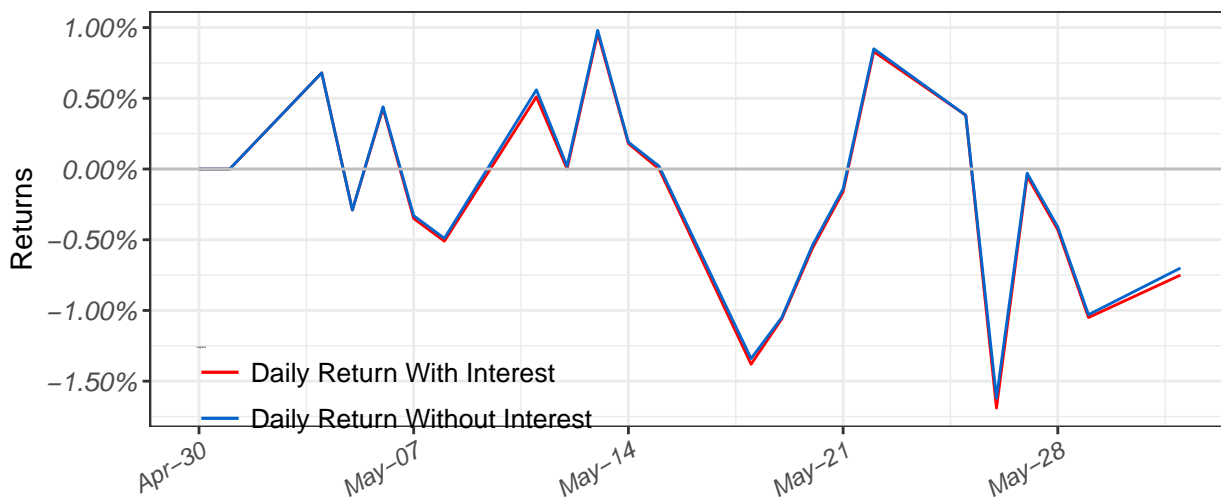
Table 7: Summary Table of USD/HUF in May

Type	CAGR	Sharpe_Ratio	MAR_Ratio
With_Interest	-41.28%	-3.697	-8.114
Without_Interest	-37.88%	-3.433	-7.820

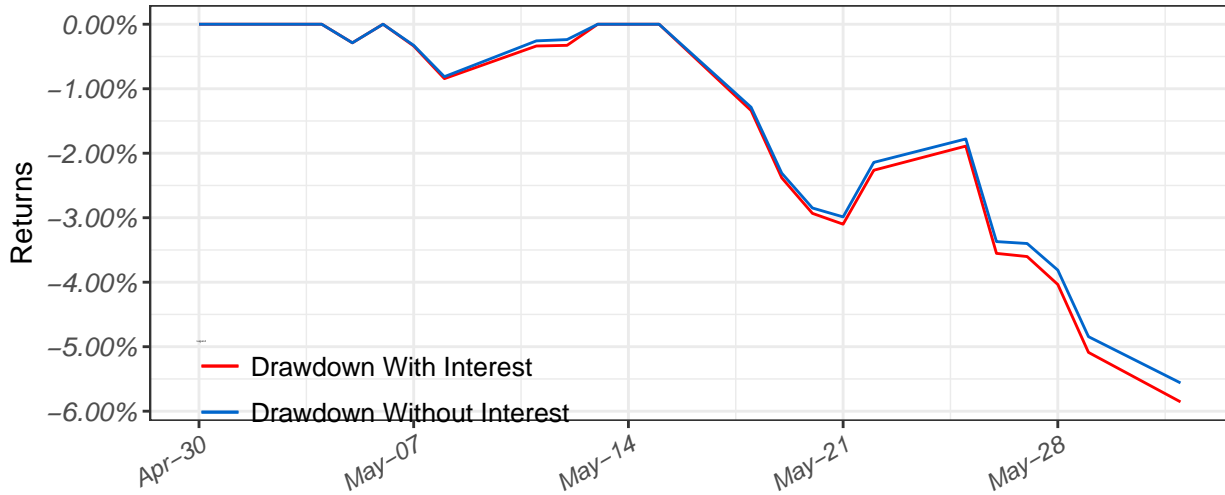
Equity Curve of USD/HUF in May



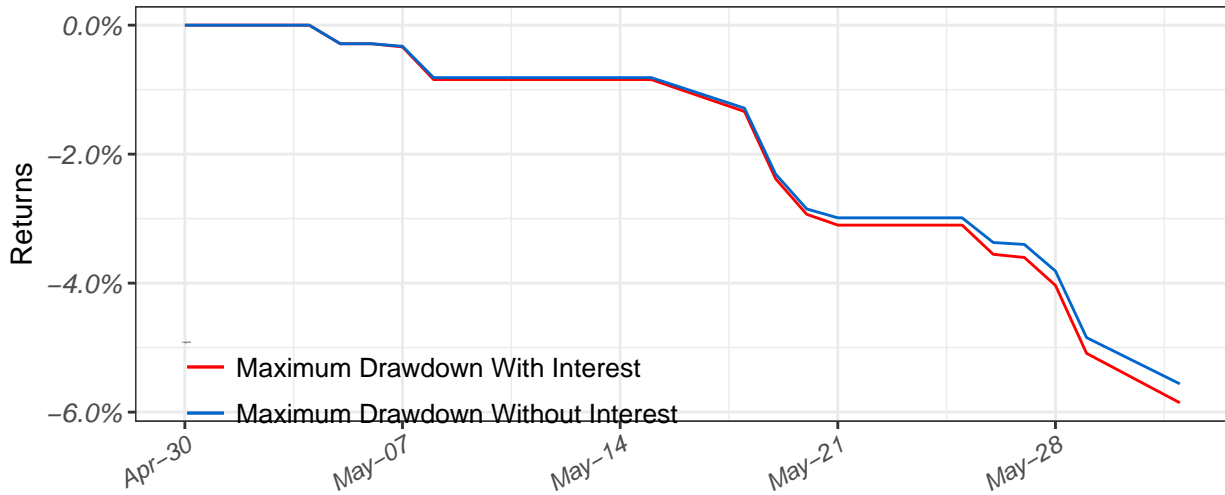
Daily Return Diagram of USD/HUF in May



Drawdown Diagram of USD/HUF in May



Max Drawdown Diagram of USD/HUF in May



4.2.4 SPY

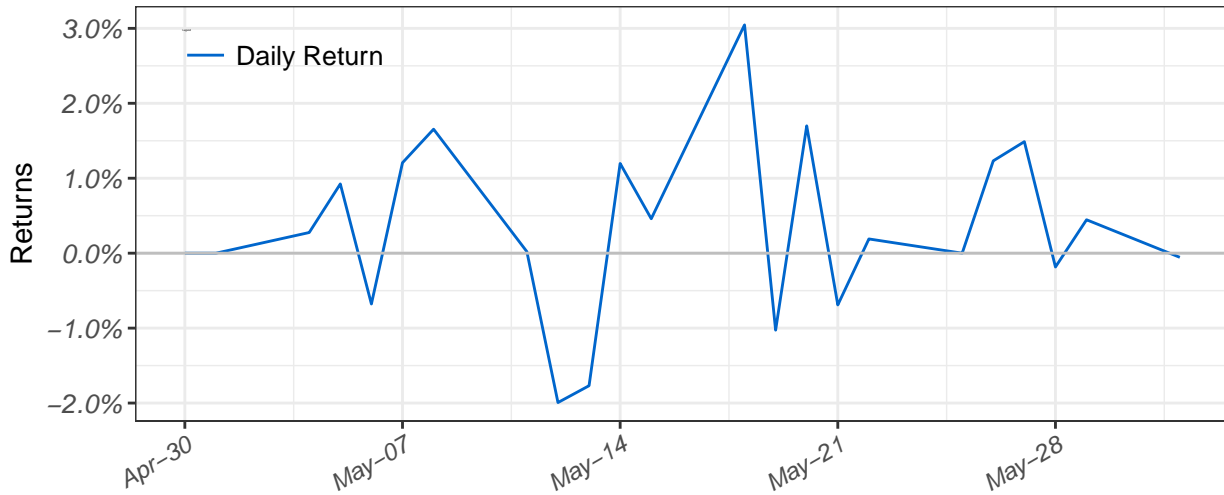
Table 8: Summary Table of SPY in May

CAGR	Sharpe_Ratio	MAR_Ratio
139.62%	7.419	37.466

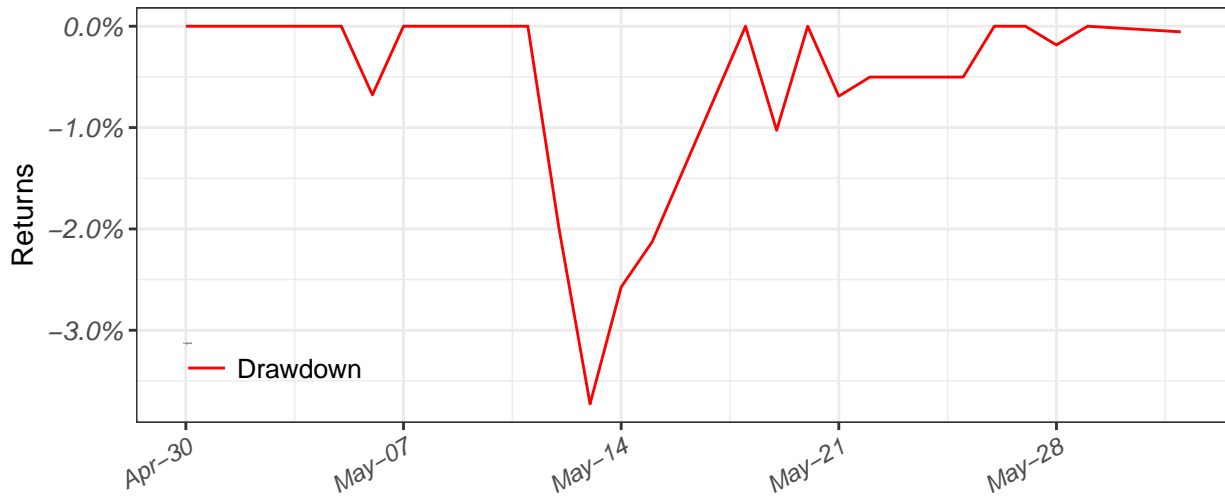
Equity Curve of SPY in May



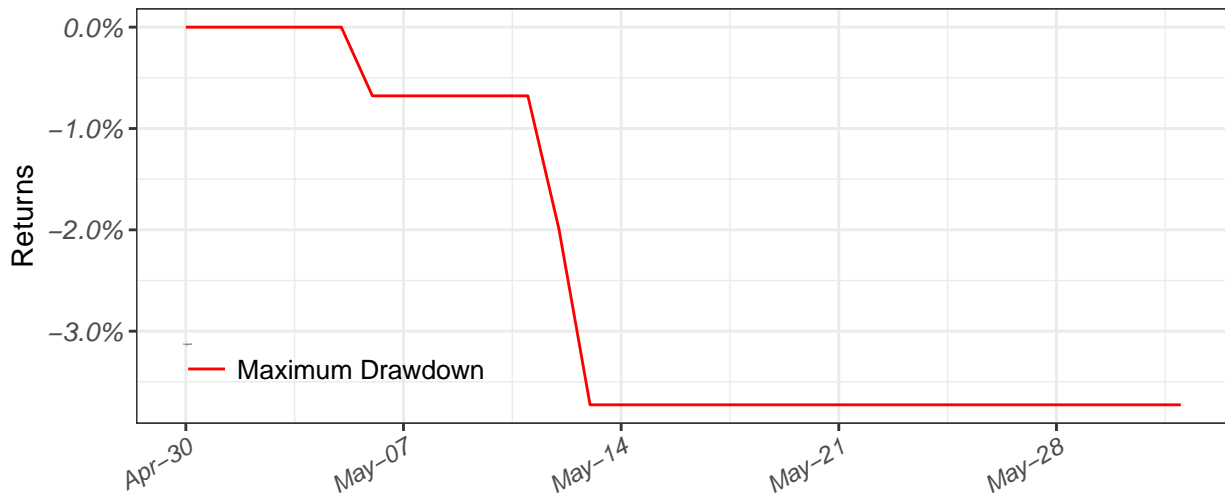
Daily Return Diagram of SPY in May



Drawdown Diagram of SPY in May



Max Drawdown Diagram of SPY in May

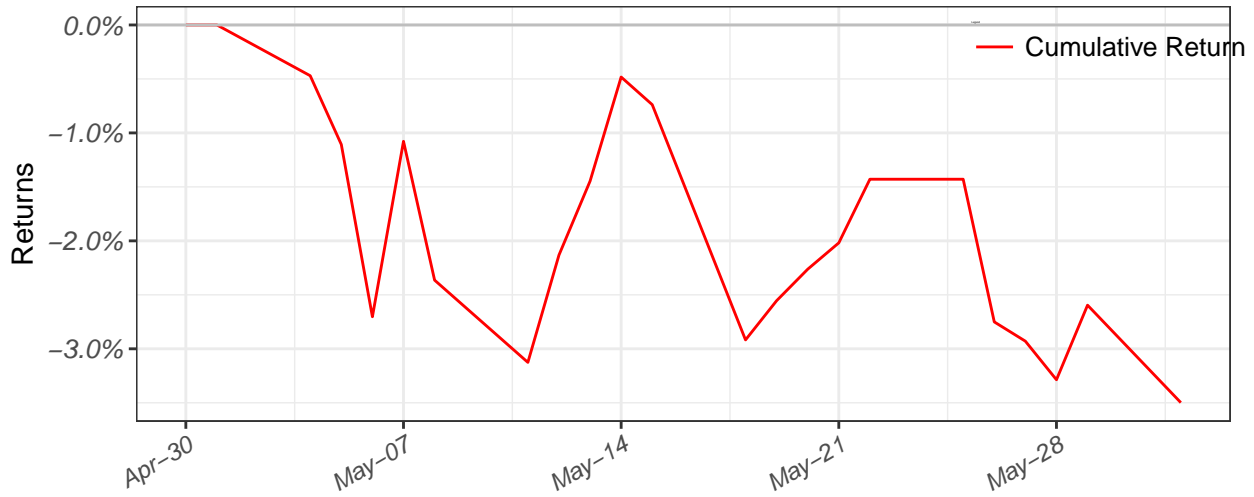


4.2.5 TLT

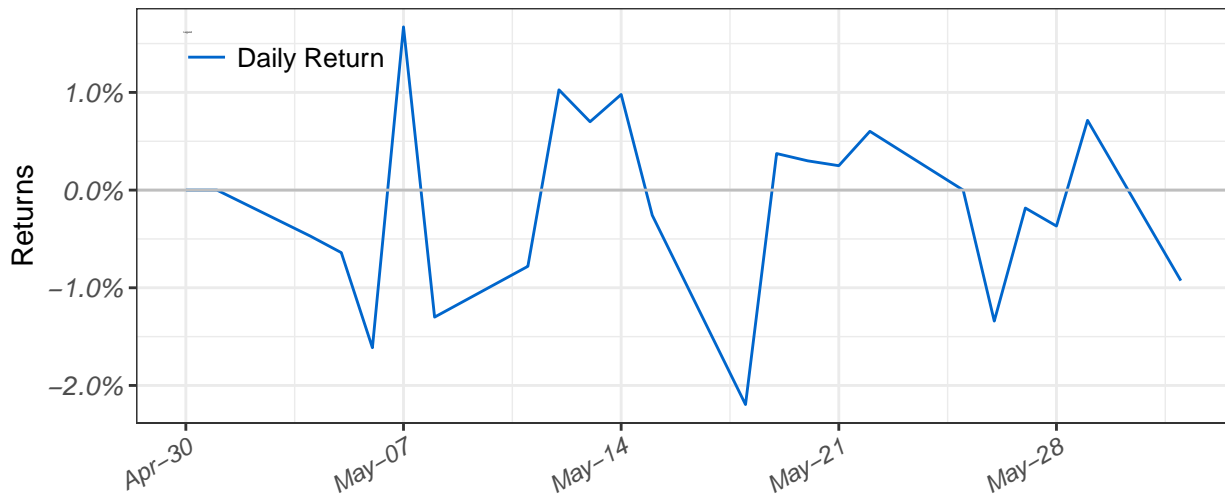
Table 9: Summary Table of TLT in May

CAGR	Sharpe_Ratio	MAR_Ratio
-34.78%	-2.294	-9.94

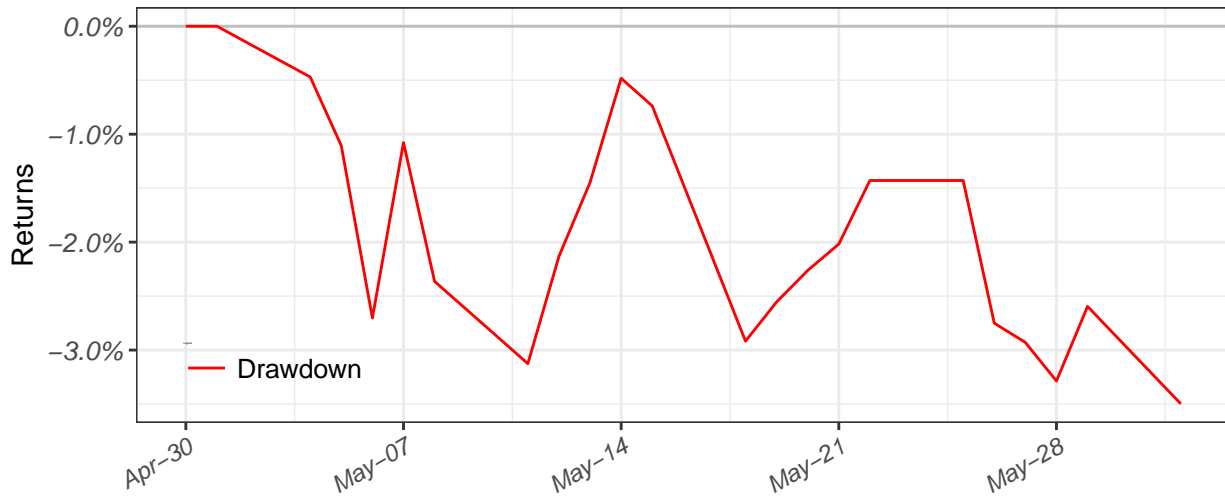
Equity Curve of TLT in May



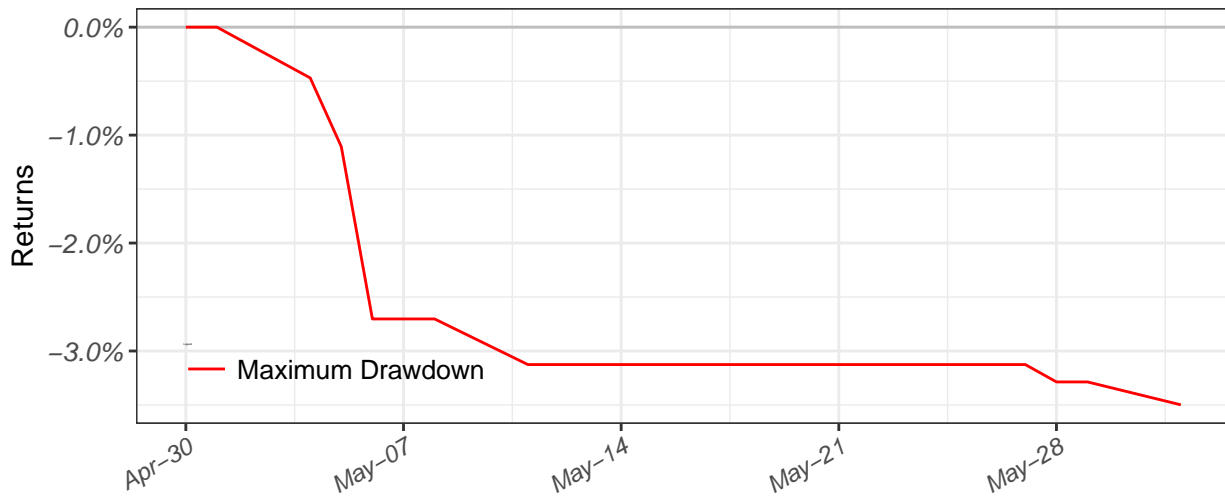
Daily Return Diagram of TLT in May



Drawdown Diagram of TLT in May



Max Drawdown Diagram of TLT in May

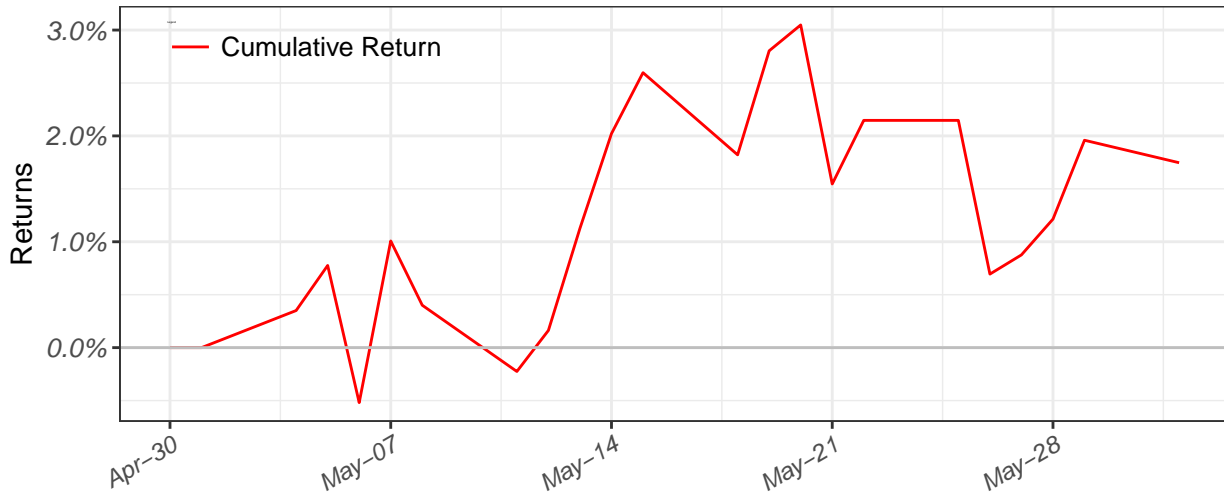


4.2.6 GLD

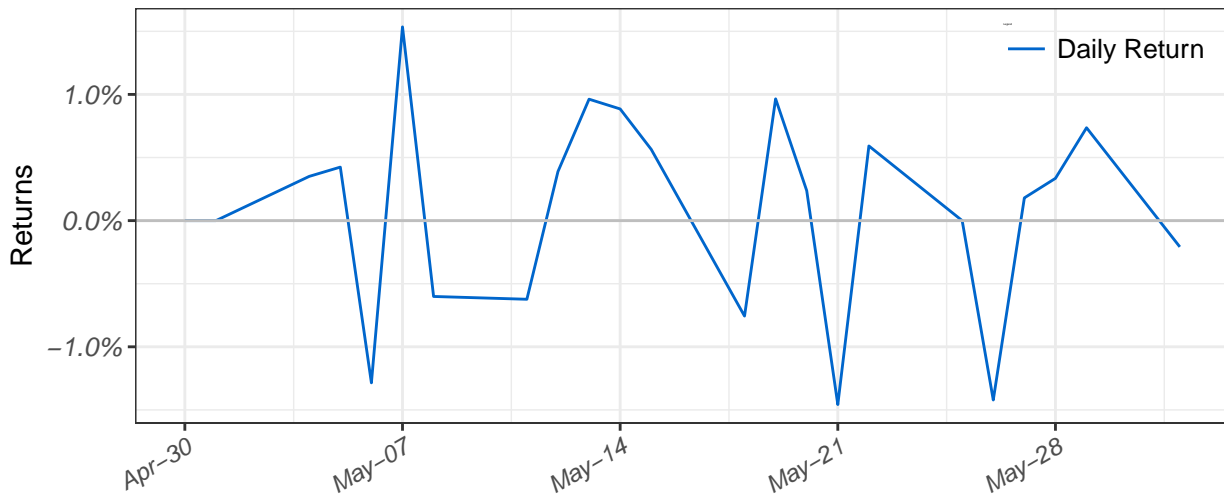
Table 10: Summary Table of GLD in May

CAGR	Sharpe_Ratio	MAR_Ratio
23.10%	1.79	10.114

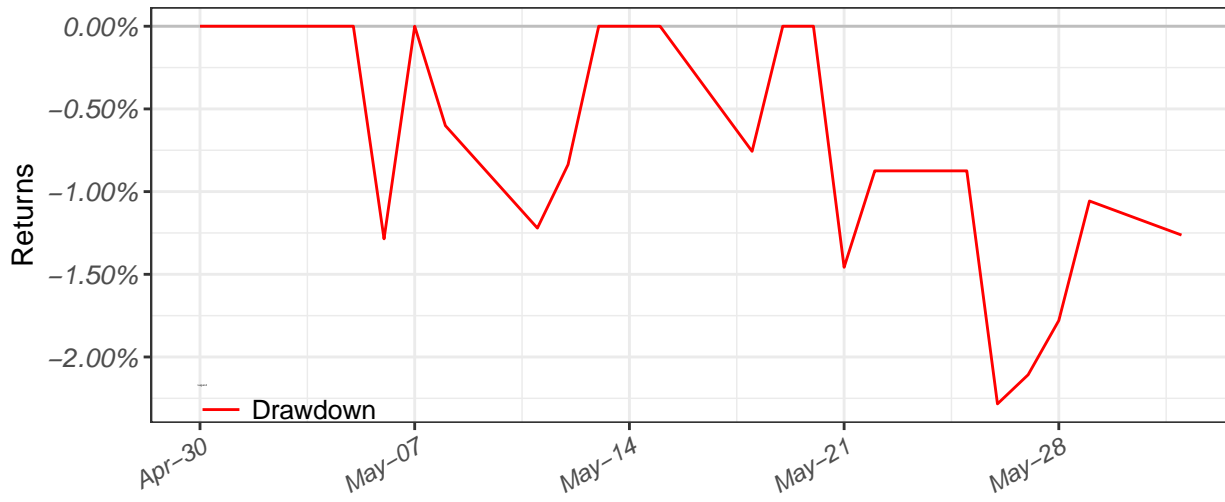
Equity Curve of GLD in May



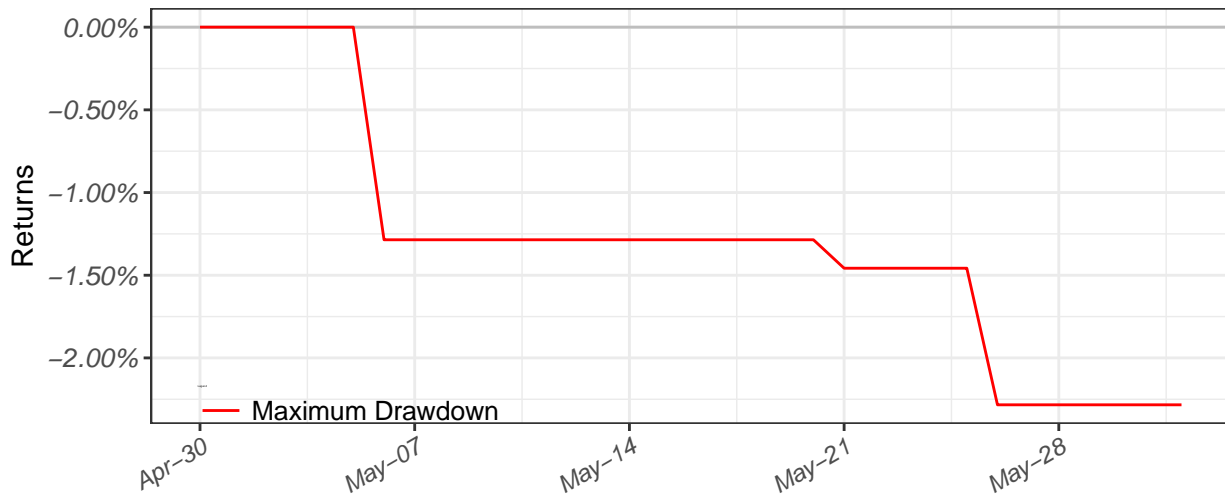
Daily Return Diagram of GLD in May



Drawdown Diagram of GLD in May



Max Drawdown Diagram of GLD in May

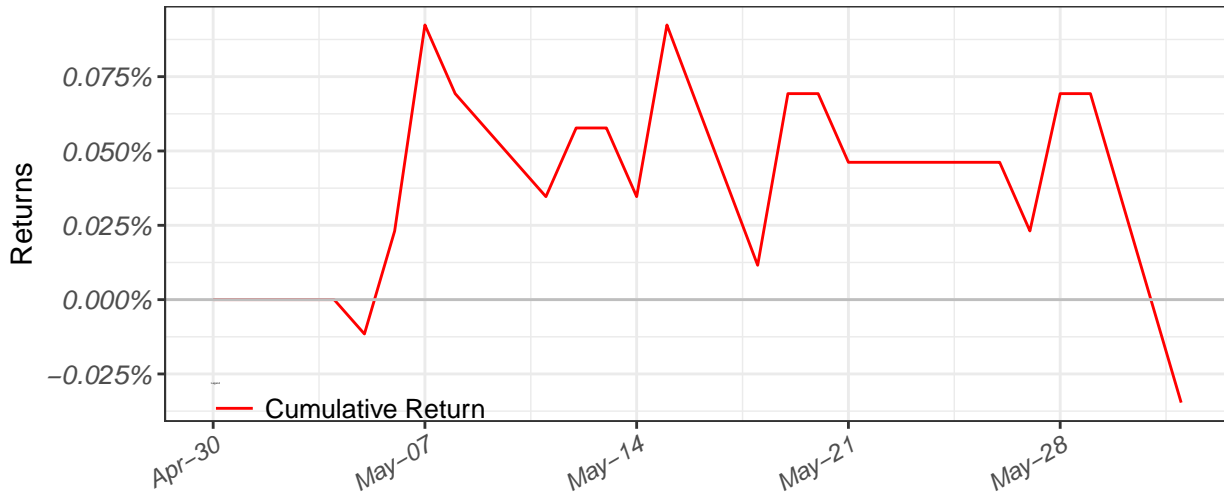


4.2.7 SHY

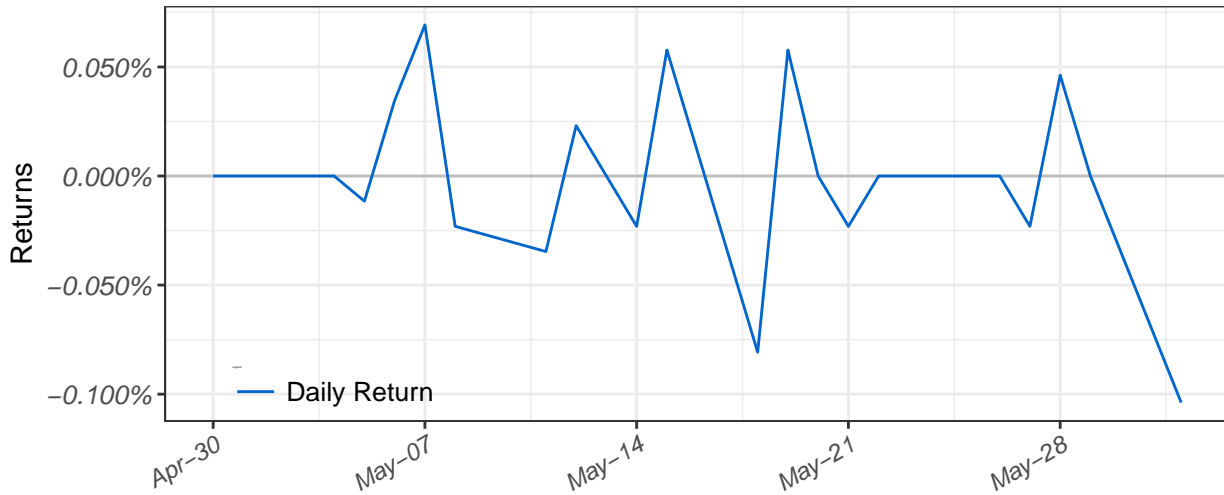
Table 11: Summary Table of SHY in May

CAGR	Sharpe_Ratio	MAR_Ratio
-0.41%	-0.631	-3.27

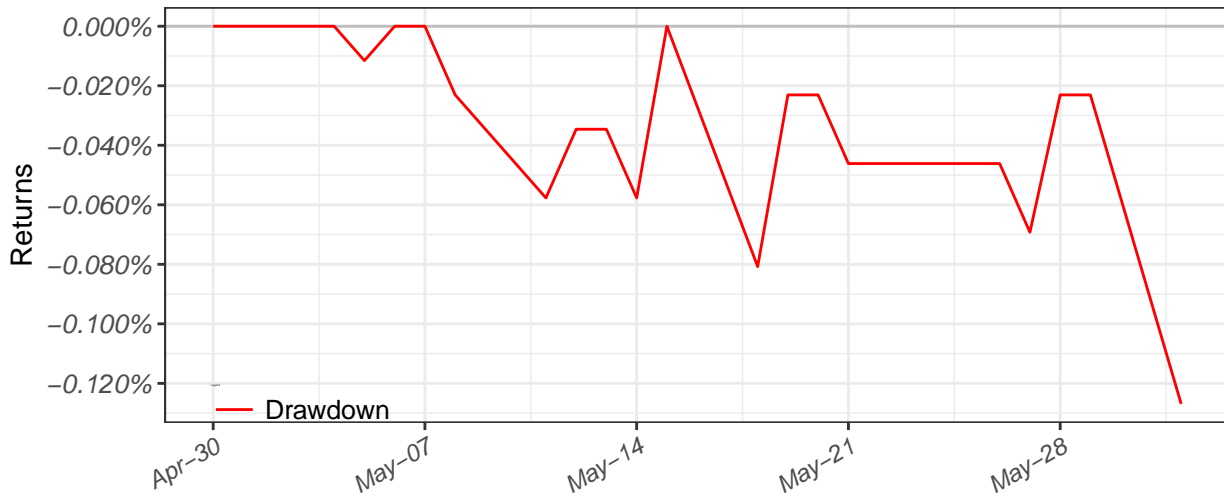
Equity Curve of SHY in May



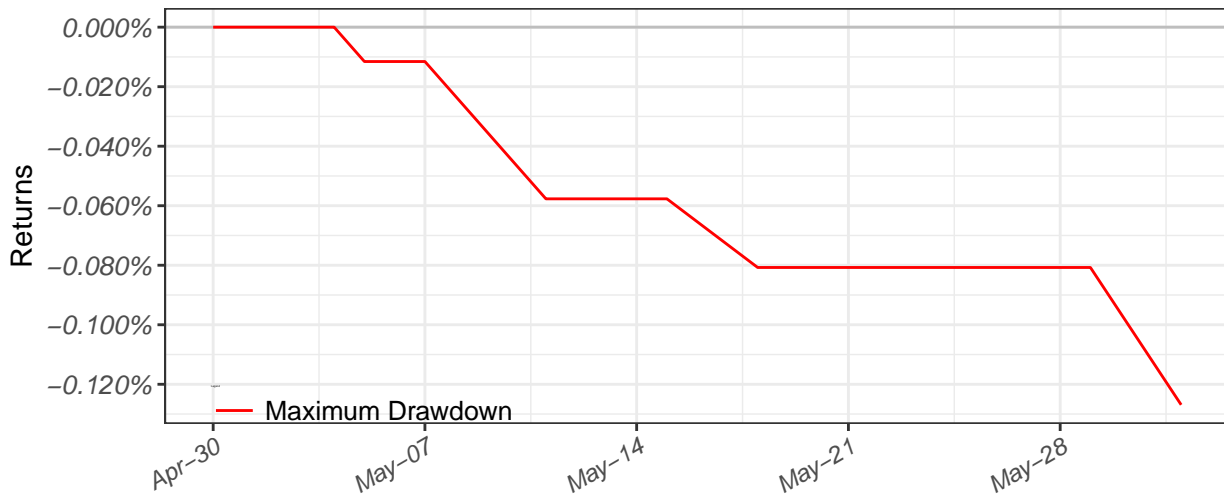
Daily Return Diagram of SHY in May



Drawdown Diagram of SHY in May



Max Drawdown Diagram of SHY in May



4.3 Comparison with the backtest result on QuantConnect

Note that an important reason for us to execute the trades through Interactive Brokers Paper Trading Account is to justify the result of paper trading through a real-life simulation. Therefore, it is very important to compare the execution result with the theoretical backtest result for a better understanding about what might be overlooked in the portfolio settings. After running the backtest from 1st May 2020 to 1st June 2020, the evaluation metrics we obtained are a CAGR of -6.92%, a Max Drawdown of 1.60%, and a Sharpe Ratio of -1.256. The following are the Equity Curve, Drawdown Diagram, and Daily Returns:

Cumulative Returns

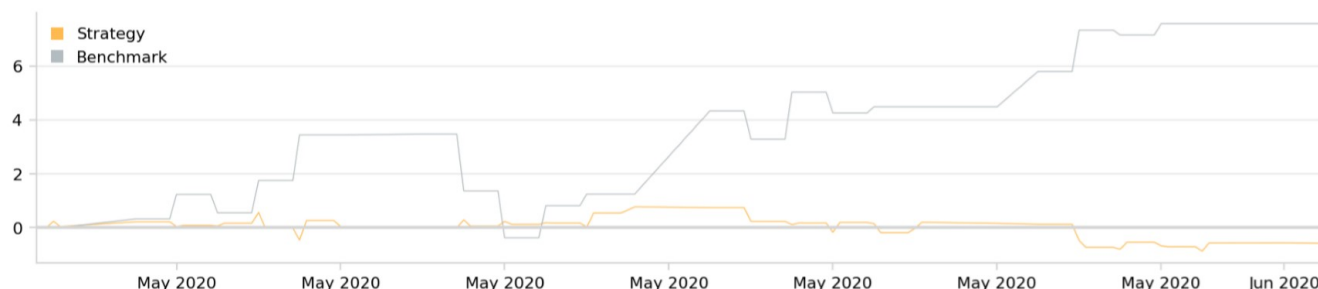


Figure 20: Equity Curve of the Portfolio in May 2020 from Backtest

Drawdown

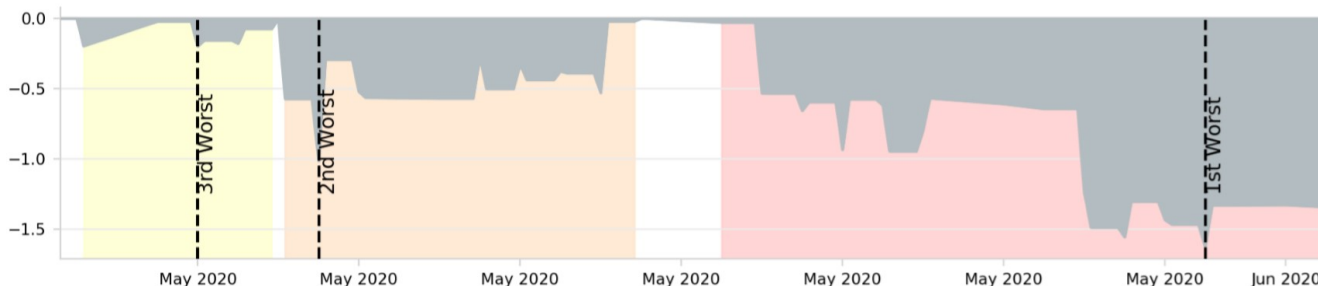


Figure 21: Drawdown Diagram of the Portfolio in May 2020 from Backtest

For similarities between the backtest and real execution, we notice that they are both not profitable from the last quarter of the month, i.e., the last week starting from 25th May 2020. Moreover, most of the daily returns pattern are similar and the backtest successfully captured a big drawdown since Mid-May.

For differences, we observe that we suffered a 1% loss on 1st June 2020 when we were closing all our positions. However, in the backtest, we cannot see any possible loss from liquidating all positions. Besides, in the backtesting, our monthly loss is around 0.65% while the one in real execution is 1.00%.

We can conclude that **the borrowing interest cost of 0.14% of total capital** in accordance with shorting other currencies in the Forex Momentum strategy and **the liquidation cost on**

Daily Returns

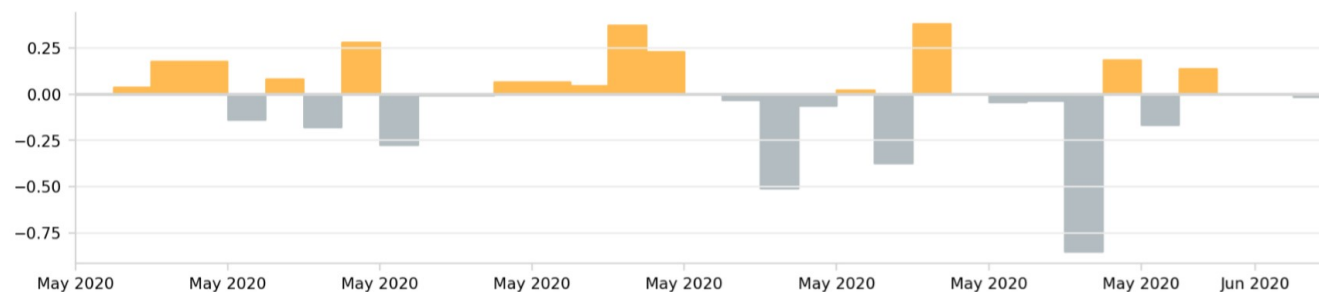


Figure 22: Daily Returns of the Portfolio in May 2020 from Backtest

the last day are the main attributes that caused the discrepancy between the backtest and the execution. Overall, our execution result reflects that the overall result from the backtest is trustworthy while we should be a bit conservative about the metrics obtained from the backtest. For the liquidation cost issue, we will discuss it shortly in Section 4.4.3.

4.4 Cost Analysis

In our portfolio, it involved buying equities, entering into long/short positions of Foreign Currencies, and manual trading on the platform. Therefore, we can categorize the cost into 3 components: Borrowing Cost for shorting other currencies, Commission Fee for transacting the financial securities, and Latency for the price differences between manual trading and backtest result due to manual trading.

4.4.1 Borrowing Cost

Throughout the 1-month trading period, the borrowing cost is equivalent to \$1360.36, which is approximately 0.14% of the original capital. However, if, for simplicity⁵, we annualized the borrowing cost, it would cost us around 1.68% annually. It is indeed a significantly large component that might be harmful to our profits.

4.4.2 Commission Fee

Since we only traded two times in May: Open and Close the positions, the total commission cost for all assets are just \$84.87. When we opened the positions on 1st May, the commission cost is \$33.50 while the one of closing the positions is \$51.37. Since it only comprises 0.0085%, even less than 1 basis point, of the original capital, we believe that the commission is an insignificant source of cost in our investment portfolio.

⁵As shown above, different currencies have different borrowing rate. Also, the cost is also dependent on the price movement of currencies.

4.4.3 Latency

Securities	Backtest		Execution		Profit			Profits_In_USD
	Start	End	Start	End	Backtest	Execution	Profit_Diff	
SPY	166097.4	-173979.5	166660.6	-177928.8	7882.1600	11268.100	3385.9400	3385.9400
TLT	166114.0	-162999.5	166753.1	-161911.9	-3114.4336	-4841.150	-1726.7164	-1726.7164
GLD	166117.0	-170556.3	166601.5	-170862.1	4439.2800	4260.630	-178.6500	-178.6500
SHY	166200.1	-166300.5	166666.5	-166647.2	100.4797	-19.250	-119.7297	-119.7297
EUR/USD	-166232.5	168851.1	-166681.0	168917.1	-2618.6009	-2236.120	382.4806	425.8921
USD/CAD	231969.7	-229058.7	234393.8	-227935.5	-2910.9674	-6458.263	-3547.2955	-2613.7183
USD/MXN	2015177.2	-1842862.4	2036326.1	-1830751.0	-172314.8200	-205575.120	-33260.3000	-1509.6185
USD/HUF	26842644.7	-25872431.6	26742393.0	-25834063.3	-970213.0600	-908329.700	61883.3600	199.7595

As we discover from the above table, our latency helped us earn some profits in SPY, EUR/USD, and HUF but damaged our profits for other components. The total Profit and Loss effect from the latency issue is:

-2136.841

The \$2136.841 loss is composed of 0.21% of the original capital, and it, together with the borrowing interest cost, perfectly explains the reason why we have 0.35% extra loss in the real execution. In conclusion, we infer that the latency issue might be an important cost in our portfolio and we would like to solve it by implementing automated trading.

5 Conclusion

In this project, we implemented 2 common forex strategies: carry trade and 252-day momentum trend-following strategy, and we finally discovered that equally allocating a sixth of the total capital into both strategies respectively along with the Permanent Portfolio could bring us a profitable and low-risk passive investing strategy. The effect is majorly from the less exposure to the equity market while incrementing the exposure to forex market. We believe that diversify our portfolio into different asset classes could benefit a lot during the normal period and, especially, the crises. Although we didn't justify our profitability of the portfolio through an 1-month paper trading, we ensure that the result in the backtest can be replicated with some adjustments from borrowing cost and latency issues.

This project is merely exploiting the profit from the U.S. Market; however, all of the components in the portfolio could be easily replicated for different states by selecting their stock index fund, gold ETF, Government Bonds, and entering into the forex contract with different base currency. We believe that the profitability of the portfolio could be much higher given since there are a lot of emerging markets where the rate of returns could be much higher due to its risk. If we could successfully control the risk of our portfolio through diversification, we believe that it is possible for us to reproduce or even improve the performance of this research in the market of other countries.

6 Future Work

In this project, although we finally discovered a better portfolio that significantly improved the risk-adjust returns of the original Permanent Portfolio, we still believe that we could further expand our works in the following aspects: base currency and corresponding Permanent Portfolio for different countries, automated trading system, permanent portfolio with volatility targeting or risk parity, and possible diversification from other asset classes or strategies.

First, as mentioned previously, we researched on the U.S. market given the limitation of the access to data. However, we would like to further investigate whether the result of our research can be reproduced in other countries and regions. For example, we may consider the performance of the Hong Kong version Permanent Portfolio with SPY, all U.S. Treasury, GLD be replaced by Hang Seng Index ETF (2833.HK), Hong Kong Government Bonds, and the Gold counterpart listed in Hong Kong (2840.HK) respectively and the forex strategies with the base currency changed into Hong Kong Dollar (HKD).

Second, even though we only had several trades on the first day of each month and the slippage or latency issues seem not to be a big problem, we believe that having an auto-trading system will minimize most of the human errors and thus secure the profits. Also, it is useful if we would like to lever up our portfolio so that the margin account can be checked by the codes automatically⁶ without possible loss in liquidation.

Third, it is shown that the performance of Permanent Portfolio can be enhanced by adopting volatility targeting for deciding the weight of components instead of equal weighting that is originally proposed by Harry Browne (Maderakis, 2019). Since the forex strategies might have 0 correlation with the Permanent Portfolio, we believe that we could easily construct such a portfolio with suitable volatility target while the profit and hedge from Forex will not be reduced.

Lastly, we could add some assets into our portfolio or some active strategies so that the performance can be improved through less concentrated exposure to certain factors, sectors or countries. For the securities to be added in the passive investment, we could consider Inflation Protected Bonds, Convertible Bonds, and some commodities; for the active strategy, we can develop pairs trading, Momentum or Mean Reversion Strategy, or even some event-driven Forex strategies.

⁶Interactive Brokers will liquidate some positions of the stocks if the number in the margin account is lower than the maintenance level at 3:30 am HKT every day

7 References

- Chen, J. (2020, March 11). Permanent Portfolio. Retrieved May 27, 2020, from <http://www.investopedia.com/terms/p/permanent-portfolio.asp>
- Cox, J. (2020, March 25). Negative rates come to the U.S.: 1-month and 3-month Treasury Bill yields are now below zero. CNBC. Retrieved from <https://www.cnbc.com/2020/03/25/negative-rates-come-to-the-us-1-month-and-3-month-treasury-bill-yields-are-now-negative.html>
- Find the Right ETF - Tools, Ratings, News. (n.d.). Retrieved May 27, 2020, from <http://www.etf.com/>
- Frazzini, A., Kabiller, D. G., & Pedersen, L. H. (2018, September 10). Buffett's Alpha. Retrieved May 27, 2020, from <https://www.cfainstitute.org/en/research/financial-analysts-journal/2018/faj-v74-n4-3>
- Maderakis, V. (2019, January 21). Permanent Portfolio by Harry Brown - Will We Ever Kill The Bug? Retrieved May 27, 2020, from <http://logical-invest.com/permanent-portfolio-will-ever-kill-bug/>
- Rohrbach, J., Suremann, S., & Osterrieder, J. (2017). Momentum and trend following trading strategies for currencies revisited-combining academia and industry. Available at SSRN 2949379.
- SPDR Gold Shares (GLD). Bringing the gold market to investors. (n.d.). Retrieved May 27, 2020, from <http://www.spdrgoldshares.com/>
- U.S. Department of the Treasury. (n.d.). Retrieved May 27, 2020, from <http://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=billrates>
- Varadi, D. (2017, July 22). What is the Proper Benchmark for Momentum or Trend-Following Strategies? Retrieved May 27, 2020, from <http://www.bsam.com/proper-benchmark-momentum-trend-following-strategies/>

8 Appendices

Appendix A: Further Investigations on number of currency pairs to long/short in FCT

A-1 Long and short 2 pairs of currencies with %GE = 200%

Cumulative Returns

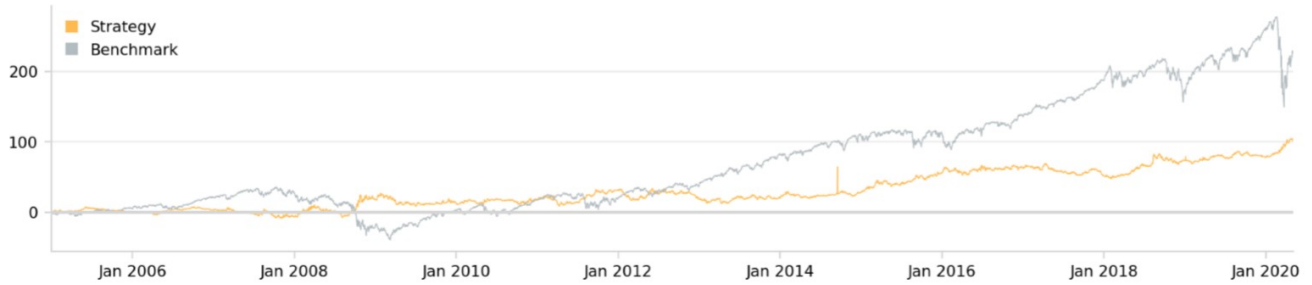


Figure 23: Equity Curve for Longing and short 2 pairs of currencies with GE = 200%

Annual Returns

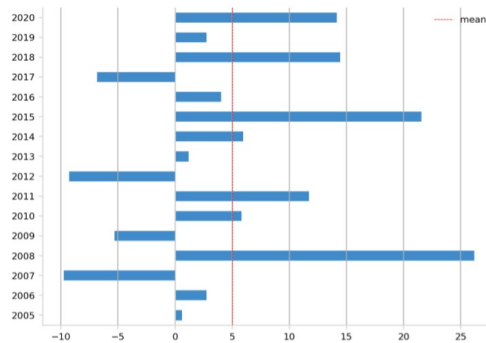


Figure 24: Annual Return Diagram for Longing and short 2 pairs of currencies with GE = 200%

A-2 Long and short 3 pairs of currencies with %GE = 200%

Cumulative Returns

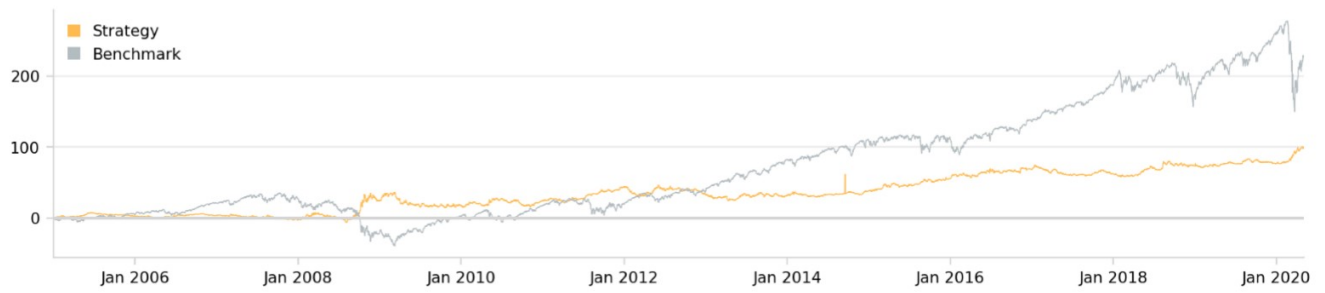


Figure 25: Equity Curve for Longing and Shorting 3 Pairs of Currencies with GE = 200%

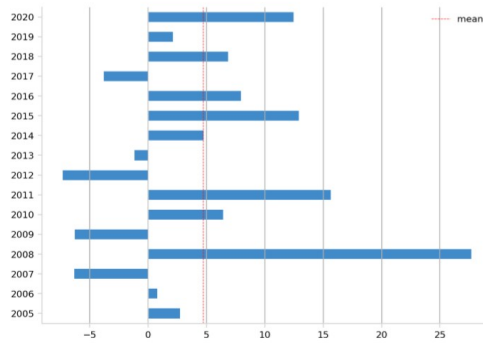


Figure 26: Annual Return Diagram for Longing and Shorting 3 Pairs of Currencies with GE = 200%

Appendix B: The full result of all 63 possible portfolios in Section 3.3

Table 12: Full Result of All 63 Portfolios

Rank	SPY	TLT	GLD	SHY	FCT	MOM	CAGR	MDD	Sharpe	SR	MAR	MR	TR
1	0%	0%	0%	100%	0%	0%	2.18%	2.20%	1.354	1	0.989	1	2
2	17%	17%	17%	17%	17%	17%	6.43%	7.40%	1.002	4	0.869	2	6
3	20%	20%	20%	20%	0%	20%	6.54%	8.20%	0.982	5	0.797	4	9
4	20%	20%	20%	0%	20%	20%	7.29%	8.80%	0.965	7	0.829	3	10
5	25%	25%	0%	25%	25%	0%	6.42%	9.40%	1.009	3	0.683	10	13
6	25%	25%	0%	25%	0%	25%	5.62%	7.30%	0.951	9	0.770	5	14
7	20%	20%	20%	20%	20%	0%	7.16%	11.00%	1.014	2	0.651	12	14
8	20%	20%	0%	20%	20%	20%	5.67%	7.50%	0.926	11	0.756	6	17
9	25%	25%	25%	0%	0%	25%	7.63%	10.70%	0.933	10	0.713	8	18
10	25%	25%	25%	0%	25%	0%	8.42%	13.60%	0.975	6	0.619	15	21
11	33%	33%	0%	0%	33%	0%	7.88%	12.30%	0.953	8	0.640	14	22
12	25%	25%	0%	0%	25%	25%	6.57%	9.20%	0.877	17	0.714	7	24
13	33%	33%	0%	0%	0%	33%	6.78%	9.60%	0.879	16	0.706	9	25
14	20%	0%	20%	20%	20%	20%	5.99%	8.80%	0.880	15	0.681	11	26
15	25%	0%	25%	25%	25%	0%	6.79%	11.50%	0.881	14	0.590	16	30
16	25%	0%	25%	0%	25%	25%	6.96%	10.80%	0.828	20	0.644	13	33
17	25%	25%	25%	25%	0%	0%	7.43%	14.80%	0.917	13	0.502	22	35
18	33%	0%	33%	0%	33%	0%	8.34%	15.10%	0.824	21	0.552	17	38
19	33%	33%	0%	33%	0%	0%	6.53%	15.10%	0.921	12	0.433	27	39
20	25%	0%	0%	25%	25%	25%	4.94%	9.00%	0.739	24	0.549	18	42
21	33%	0%	0%	33%	33%	0%	5.70%	10.80%	0.800	22	0.527	20	42
22	33%	33%	33%	0%	0%	0%	9.14%	20.20%	0.862	18	0.453	24	42
23	25%	0%	25%	25%	0%	25%	6.00%	11.90%	0.772	23	0.504	21	44
24	0%	25%	25%	25%	0%	25%	5.78%	10.70%	0.708	27	0.541	19	46
25	33%	0%	33%	0%	0%	33%	7.25%	16.40%	0.709	26	0.442	25	51
26	50%	0%	0%	0%	50%	0%	7.53%	18.90%	0.713	25	0.398	30	55
27	0%	33%	33%	0%	0%	33%	6.94%	14.20%	0.663	34	0.489	23	57
28	0%	33%	33%	33%	0%	0%	6.79%	16.60%	0.702	29	0.409	28	57
29	33%	0%	0%	0%	33%	33%	5.89%	13.50%	0.671	32	0.436	26	58
30	50%	50%	0%	0%	0%	0%	8.65%	24.60%	0.830	19	0.352	39	58
31	0%	20%	20%	20%	20%	20%	5.75%	14.20%	0.684	31	0.405	29	60
32	0%	25%	25%	25%	25%	0%	6.52%	17.80%	0.704	28	0.366	35	63
33	0%	25%	25%	0%	25%	25%	6.62%	17.50%	0.651	36	0.378	33	69
34	0%	50%	50%	0%	0%	0%	8.94%	24.10%	0.653	35	0.371	34	69
35	33%	0%	0%	33%	0%	33%	4.61%	11.70%	0.608	39	0.394	31	70
36	0%	33%	33%	0%	33%	0%	7.93%	23.00%	0.670	33	0.345	40	73
37	33%	0%	33%	33%	0%	0%	6.98%	22.20%	0.688	30	0.314	44	74
38	0%	50%	0%	50%	0%	0%	5.18%	14.40%	0.601	40	0.359	37	77
39	0%	33%	0%	33%	0%	33%	4.32%	11.10%	0.547	47	0.389	32	79
40	0%	33%	0%	33%	33%	0%	5.32%	14.60%	0.562	45	0.364	36	81
41	0%	0%	33%	33%	0%	33%	4.87%	14.30%	0.581	42	0.341	41	83
42	0%	25%	0%	25%	25%	25%	4.62%	13.00%	0.526	48	0.355	38	86
43	0%	0%	33%	33%	33%	0%	5.85%	21.00%	0.626	37	0.279	49	86
44	0%	0%	25%	25%	25%	25%	5.05%	17.30%	0.597	41	0.292	47	88
45	50%	0%	50%	0%	0%	0%	9.20%	33.10%	0.621	38	0.278	50	88
46	0%	50%	0%	0%	50%	0%	6.84%	21.20%	0.517	51	0.323	42	93

Table 12: Full Result of All 63 Portfolios (*continued*)

Rank	SPY	TLT	GLD	SHY	FCT	MOM	CAGR	MDD	Sharpe	SR	MAR	MR	TR
47	0%	0%	50%	0%	50%	0%	7.61%	30.40%	0.575	43	0.250	53	96
48	0%	100%	0%	0%	0%	0%	7.85%	26.50%	0.517	52	0.296	46	98
49	0%	0%	33%	0%	33%	33%	5.97%	22.70%	0.550	46	0.263	52	98
50	0%	50%	0%	0%	0%	50%	5.30%	16.40%	0.480	56	0.323	43	99
51	0%	0%	50%	50%	0%	0%	5.92%	24.50%	0.567	44	0.242	55	99
52	0%	33%	0%	0%	33%	33%	5.40%	17.30%	0.484	55	0.312	45	100
53	0%	0%	50%	0%	0%	50%	6.10%	21.20%	0.511	53	0.288	48	101
54	50%	0%	0%	0%	0%	50%	5.78%	21.50%	0.521	50	0.269	51	101
55	50%	0%	0%	50%	0%	0%	5.39%	29.10%	0.522	49	0.185	59	108
56	0%	0%	100%	0%	0%	0%	9.01%	45.50%	0.486	54	0.198	57	111
57	0%	0%	0%	50%	50%	0%	3.80%	15.40%	0.418	58	0.246	54	112
58	0%	0%	0%	33%	33%	33%	3.32%	15.60%	0.376	59	0.213	56	115
59	100%	0%	0%	0%	0%	0%	8.03%	55.10%	0.426	57	0.146	62	119
60	0%	0%	0%	50%	0%	50%	2.27%	11.80%	0.303	63	0.192	58	121
61	0%	0%	0%	0%	50%	50%	3.82%	22.70%	0.316	62	0.168	60	122
62	0%	0%	0%	0%	100%	0%	5.35%	32.40%	0.346	61	0.165	61	122
63	0%	0%	0%	0%	0%	100%	4.34%	35.60%	0.363	60	0.122	63	123

Appendix C: Complete information of the optimal portfolio

Monthly Returns

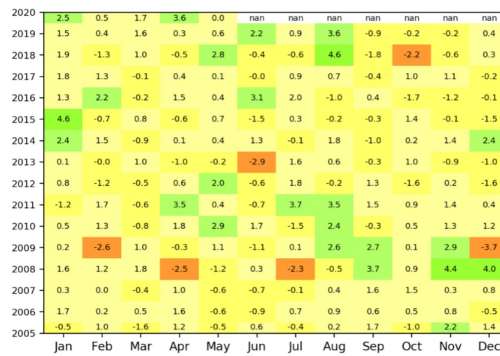


Figure 27: Monthly Return Diagram for the Optimal Portfolio

Return Histogram

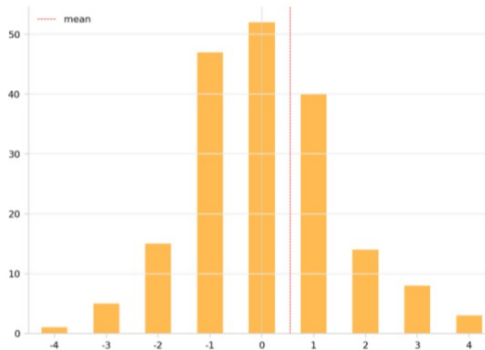


Figure 28: Return Histogram for the Optimal Portfolio

Drawdown

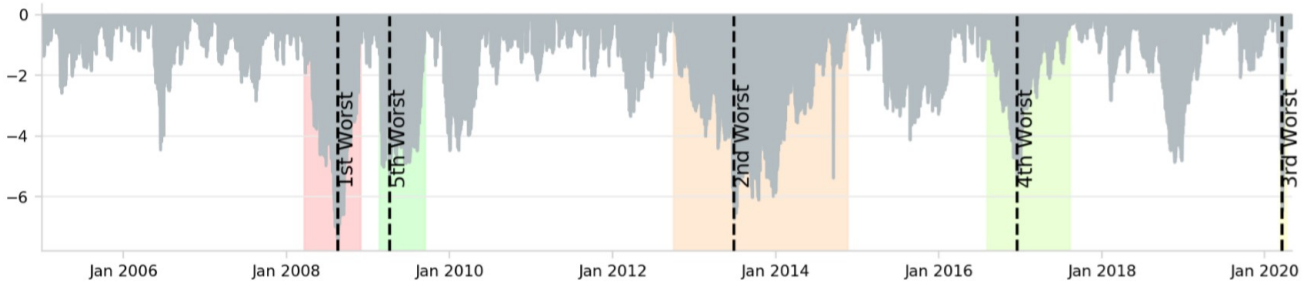


Figure 29: Drawdown Diagram for the Optimal Portfolio

Rolling Sharpe Ratio (6 Months)



Figure 30: Rolling Sharpe Ratio for the Optimal Portfolio