Factor Timing Project

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Chapter 1

Introduction and Reference Portfolio

The traditional approach of choosing factors has been challenged in recent years since many factors failed to consistently explain long-term performance of stock returns. During economic recessions, the traditional static factor selection approach also suffered from large drawdown and lengthy recovery period. In order to enhance returns and reduce risks, some investors took much effort of identifying new factors that can generate consistent alpha; while others devoted to adapting existing factors by incorporating dynamic factor selection and dynamic factor timing.

This paper focuses on the "timing" part of asset management by conceiving a dynamic asset allocation strategy of dynamic factor selection and timely exposure shifting across dynamic factors. The objective of our asset allocation strategy is to generate outperformance relative to a reference portfolio. However, the purpose of this paper is to demonstrate our factor timing analysis including the definition of factor universe, the dynamic rebalancing rules, the criterion of dynamic factor selection and exposure shifting, and the evaluation of our strategy.

1.1 Choose a Reference Portfolio

We adopt the 2015 reference portfolio of the New Zealand Superannuation Fund, and assume our target investors are long-term US-based investors with no direct liabilities. The reference portfolio is supposed to be reviewed by the Guardians of New Zealand Superannuation at lease once every five years. Therefore, we propose our investment horizon is a long term for at lease 5 years.

According to the design priciples of NZSF's reference portfolio, the Fund is aimed to assist the New Zealand (NZ) Government in smoothing the future tax burden of superannuation payments. The Guardians' mandate is to invest the Fund to maximize return without undue risk, while employing best practice portfolio management and avoiding prejudice to NZ's reputation as a responsible member of the world community.

To fulfill the mandate of maximizing return without undue risk, the reference portfolio allocates 80% to growth (equity-like) assets and 20% to fixed-income assets with enhanced diversification by combining broad market exposures to global equities and global bonds. As we mentioned before, the Fund's endowment is long-term investors with no direct liabilities, we claim that those investors have high risk tolerance towards equity risk.

Given the decisions about the composition of the reference portfolio made by the Guardian's Board, the reference portfolio is a simple, low-cost and passive portfolio that contains only traditional asset classes.

1.2 Asset Allocations of Reference Portfolio

The following table illustrates the asset classes and their corresponding weights in the reference portfolio. The proposed indices are selected with the considerations of implementation. For example, an equity market index should reflect the complete investable universe and it can be closely replicated by an investor. Moreover, we select the market index with the contituent stocks which can be traded in a liquid market with minimum transaction costs.

Asset Class	**Proposed Index**	**Weight**
Developed Market Equities	MSCI World Investable Market Index	65%
Emerging Market Equities	MSCI Emerging Market Investable Market Index	10%
New Zealand Equities	NZX 50 Gross Index	5%
Global Fixed interest	Barclays Capital Global Aggregate Index	20%

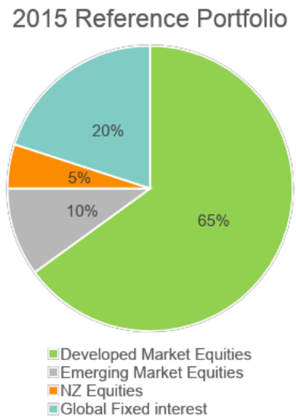

Figure 1.1: 2015 Reference Portfolio Asset Allocations

1.3 Benchmark Portfolio

Based on the asset classes and their proposed indices, we collected the long-term return data for each asset (market index) and constructed the reference portfolio according to its asset allocations at the initial point. We held this reference portfolio without any rebalancing and tracked its performance over years.

On the other hand, we consider a simple rebalanced portfolio which readjusts the asset allocations to its original allocations every quarter. We believe the quarterly rebalanced portfolio is appropriate in the sense that it takes into account both the transaction costs from rebalancing and the deviation from the original portfolio construction. Therefore, we treat this simple quarterly rebalanced portfolio as the benchmark which our factor timing strategy is aimed to outperform.

Figure 1.2 displays the cumulative returns of the reference portfolio and the benchmark portfolio with quarterly rebalancing respectively.

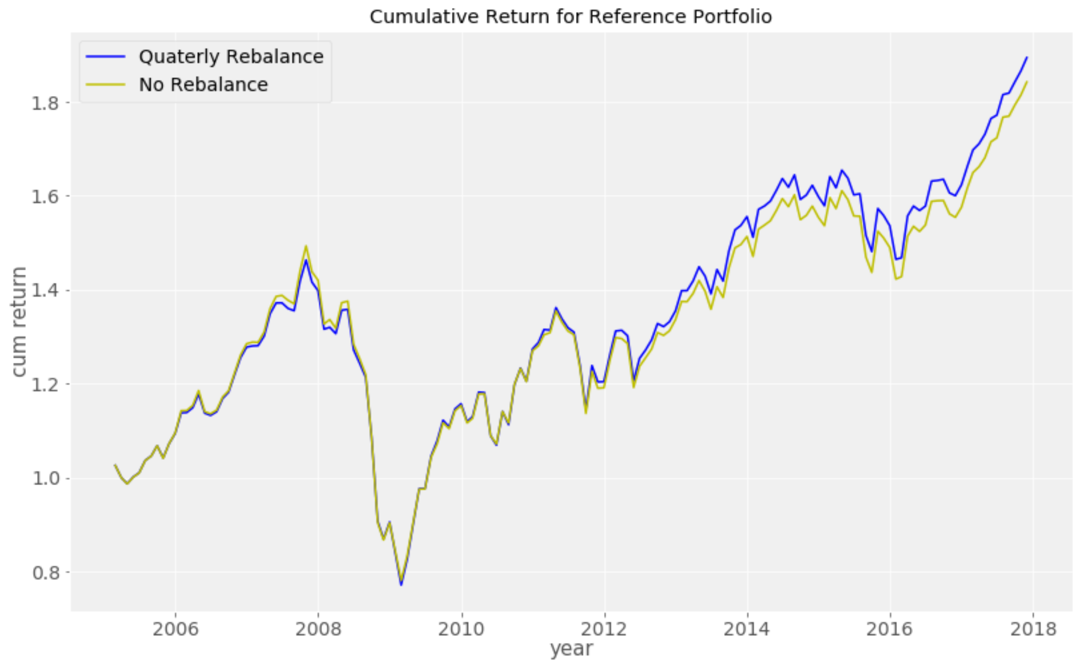

Figure 1.2: Reference vs. Benchmark Portfolios

Comparing the cumulative returns of each portfolio, we observed that the reference portfolio (without rebalancing) outperform the benchmark (quarterly rebalanced) right before the GFC, but was followed by larger drawdown during the crisis. The possible explanation is the housing bubble before the GFC stimulated the equity market to appear ephemeral bullish. Majority of returns of the reference portfolio is subject to equities, especially developed market equities. Therefore, without forcing a fixed allocation to equities, the reference portfolio gradually assigned more weights to equities than the proposed 80%, which generates its outperformance relative to the benchmark before the GFC. The high returns are always associated with high risks. During the crisis, the reference portfolio had larger drawdown because most of its risks were attributed to its large allocations in equities. After the GFC, as the equity market rebounded, these two portfolios experienced similar performance. However, after the recession in 2013 the benchmark portfolio gradually outperformed the reference portfolio.

Chapter 2

Factor Universe

We included various potential factors in our universe. They can be classified in to two types: the bond related factors and stock related factors. Below, we will list the factors and explain the intuition behind them. These factors will later be used for constructing the re-balancing strategies. To the limit of this assignment, we will only look at factors present in the US market. All the factors' values are normalized to monthly average.

2.1 Bond Related Factors:

Inflation: We used monthly CPI data from Bureau of Labor Statistics.

Credit Spread: OAS (Option Adjusted Spread) of the ICE BofAMI US Corporate BBB Index, which is the index tracking the performance of US dollar denominated investment grade rate corporate debt that are publicly issued in the US.

Interest Rate Spread: We used the difference between the yield of 10-Year Treasury Constant Maturity bond and that of 2-Year Treasury Constant Maturity bond.

2.2 Stock Related Factors

Fama/French 5 factors: SMB, HMI, RMW, CMA, $R_m - R_r$

VIX: Data is pulled from CBOE website.

Market Sentiments: We added AAII (American Association of Individual Investors) Investor Sentiment Data to measure market sentiments. This data come from the votes of top ranked investors in AAII about whether they're bullish or bearish about the market.

Chapter 3

Simple Investment Strategies

This chapter will introduce several simple rules used to rebalance the portfolio without adding factors.

3.1 Rebalance with Target Weights

There are many different ways to rebalance the portfolio with a set of target weights. The target weights used here are the set of assets weights in the reference portfolio. Hence, we would like to invest 65% in developed market equities, 10% in emerging market equities, 5% in New Zealand equities, and 20% in global fixed interest rate.

3.1.1 Rebalancing rules

There are three types of rules for sustaining the same asset allocation. They are: rebalancing by timing, rebalancing by threshold and rebalancing by timing and threshold.

- Rebalance by timing
  If a portfolio manager decides to rebalance by timing, he/she only needs to take the rebalance frequency into consideration. For an example, the portfolio manager could choose to rebalance the weights of the portfolio back to the target weights on a daily basis. The frequency usually varies from daily to yearly. Possible choices include daily, monthly, quarterly, semiannually and annually rebalance. If the portfolio manager is pretty risk averse, he/she would not be willing to deviate too much from the target weights and would choose to rebalance quiet more often than risk seeking portfolio managers.

- Rebalance by threshold
  A threshold is the maximum deviation from the target weight. When rebalancing by threshold, the portfolio manager would not conduct the rebalancing process unless at least one asset's weight deviate more than the threshold. For an example, if the threshold is 5% and the weight for the developed market equity goes to 70.1% or 59.9%, the portfolio should be rebalanced back to the target weights. Hence, if the volatility of the market is too high or the threshold is set too low, the portfolio might need to be rebalanced frequently.

- Rebalance by timing and threshold
  Rebalance by timing and threshold is a combination of the previous two. If conditions for timing and threshold are not satisfied at the same time, the rebalance would not be taken. For instance, one portfolio manager sets the rebalancing frequency to be monthly and the threshold to be 5%. Then at the end of the month, the manager would take a look at each asset's weight. If the deviation is not larger than the 5%threshold, the portfolio manager would not rebalance the portfolio. This rebalancing rule is expected to achieve a much lower real rebalancing frequency comparing with the previous two rules.

3.1.2 Empirical results

According to those three kinds of rules introduced previously, we conducted back test on those rules by using the historical data. The portfolio is assumed to be constructed on January 1st, 2005.

Trading cost and holding cost are considered in calculating the value and the return for the portfolio. In terms of trading cost, according the table contained in the project material, the trading costs for developed market equities, emerging market equities, New Zealand equities and global fixed interest rate are set to be 0.1167%, 0.20%, 0.10% and 0.19% respectively. This cost is charged from the portfolio value whenever a trade is made. The holding costs are charged annually and are set to be 0.067%, 0.20%, 0.1% and 0.09% respectively.

The empirical results are demonstrated below accordingly.

- Rebalance by timing
  For this rule, we have tried monthly, quarterly and annually rebalancing.

The cumulative return is calculated for each case. For comparison, the cumulative return for the portfolio without rebalancing is also calculated. Those cumulative returns are plotted in the graph below.

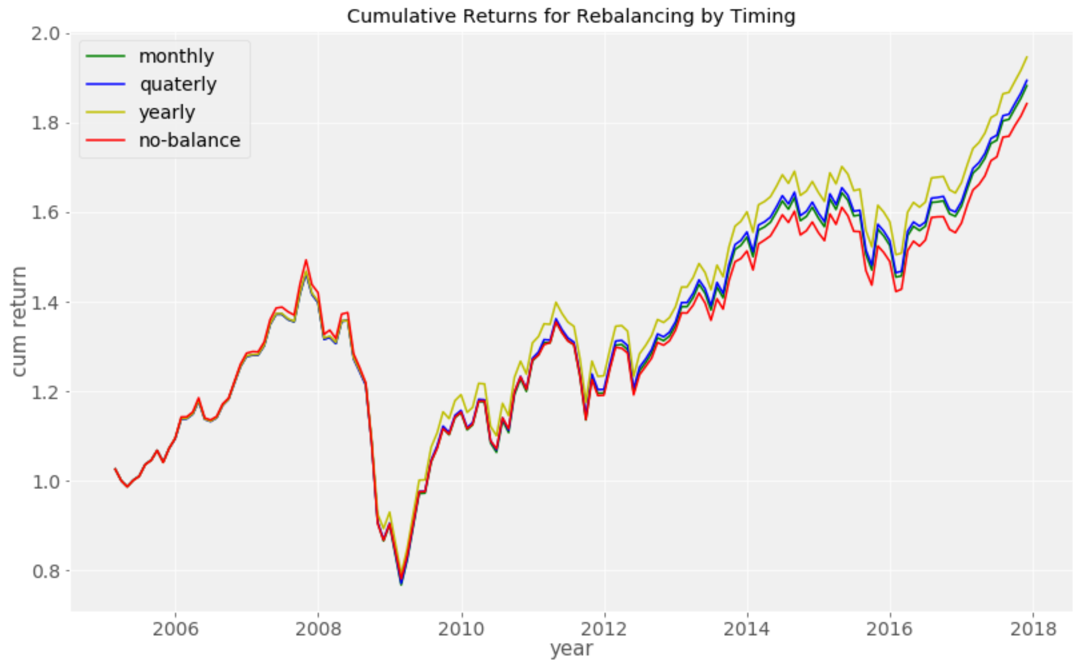

Figure 3.1: Cumulative return for rebalancing by timing

From the plot, it could be observed that there is a significant change in the relationship between rebalancing and not rebalancing. Before 2008, the cumulative return for portfolio without rebalancing is close to the cumulative return for rebalanced portfolios. Specifically, the former slightly dominated the latter. However, after 2008, the portfolio with annually rebalance gradually dominates the rest portfolios.

A possible explanation could be, before the 2008 recession, the relative relationship between returns for those four assets in the portfolio did not change much. This fact is illustrated in the plot below. Hence, without rebalancing, the asset with the highest return would tend to gradually have a higher weight. As a result, the portfolio benefited from this increasing weight. If the weights are rebalanced back to the target weight, the portfolio return would decrease as more weight are put on less increased asset. After 2008, the relative relationship between assets' returns fluctuated a lot. Hence, rebalancing back to the target rate helped to increase the cumulative return. Meanwhile, rebalancing too often caused an increase in the trading cost and hurt the profitability. As a result, the portfolio rebalanced annually got a highest cumulative return.

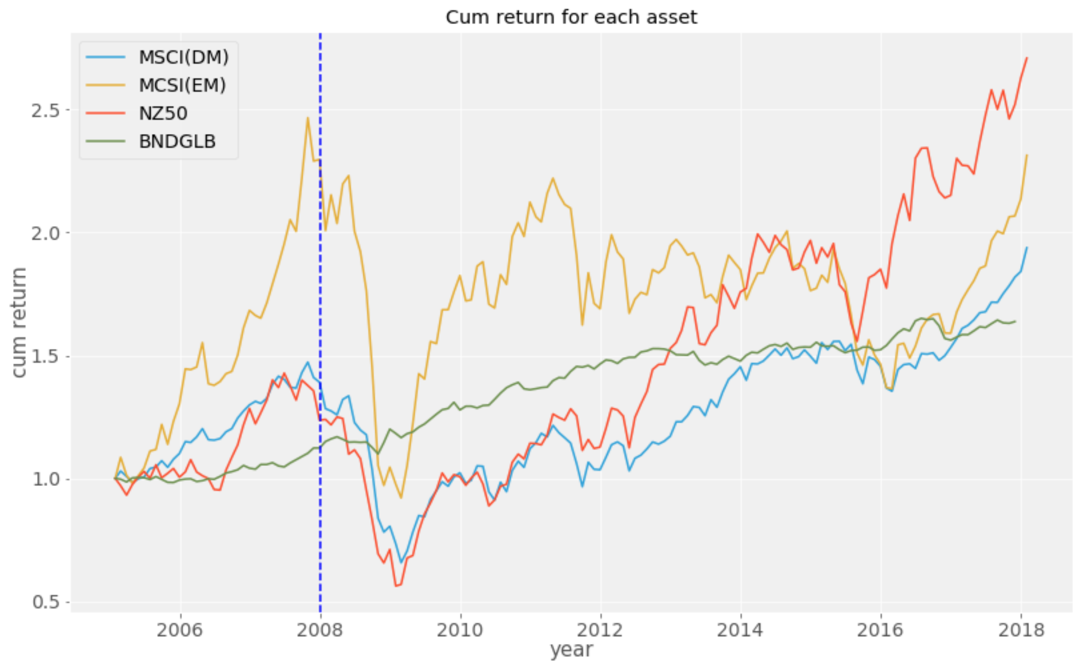

Figure 3.2: Cumulative return for assets in the portfolio

- Rebalance by threshold
  Similar as the previous rule, three different rebalancing methods are tried here. They are: rebalancing by 5% threshold, rebalancing by 10% threshold and rebalancing by 15% threshold. Cumulative returns are calculated and compared. The plot below shows all cumulative returns.

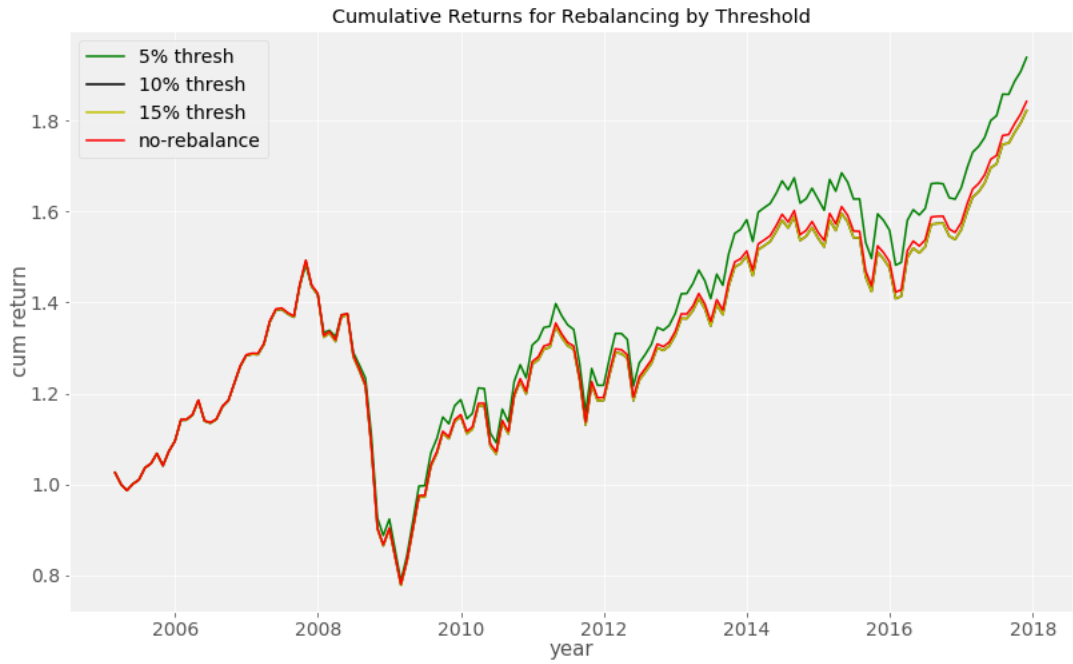

Figure 3.3: Cumulative return for rebalancing by threshold

The plot above states a similar pattern as Figure 3.1. Before the recession, no-rebalancing portfolio dominated all the other portfolios. However, after the recession, portfolio with a 5% rebalancing threshold gradually got the highest return and dominated the rest portfolios. This result demonstrated that, after the recession, the target weights could work the best to optimize the portfolio return. If deviate too much from the target weights, the cumulative return of the portfolio could not earn the highest increase. Besides, this plot also demonstrates that, assets in the portfolio rarely had a deviation larger than 10% or 15%, otherwise the cumulative returns for 10% threshold and 15% threshold should not have been so close to the cumulative return of the no-rebalancing portfolio.

- Rebalance by timing and threshold
  When rebalancing by timing and threshold, three possible combinations are tried. They are: rebalancing monthly with a 5% threshold, rebalancing quarterly with a 10% threshold and rebalancing annually with a 15% threshold. The cumulative returns for those three rules are plotted below.

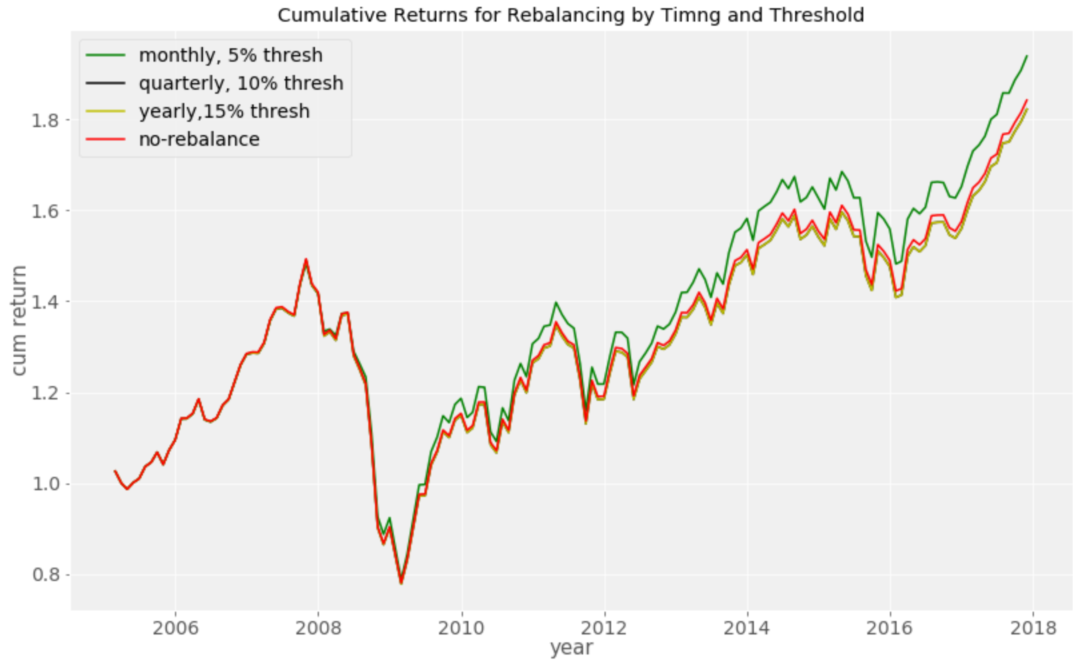

Figure 3.4: Cumulative return for rebalancing by threshold

The plot above is similar with Figure 3.3. There are two main reasons. Firstly, rebalancing monthly with a 5% threshold is the same with only rebalancing with a 5% threshold as monthly data are used here. Secondly, it is very hard to satisfy both the 10% threshold and quarterly rebalancing conditions at the same time, not to mention the 15% threshold and annually rebalancing. Hence, those latter two rules have a similar cumulative curve with the no-rebalancing one.

In summary, there are three interesting facts about rebalancing with a target weights.

First of all, the recession in 2008 greatly changed the performance of rebalancing rules. Before 2008, no-rebalancing always dominates the other rules in terms of cumulative returns. However, after 2008, rebalancing annually or with a 5% threshold could easily earn a higher cumulative return than the no-rebalancing rule.

Second, no single rebalancing rule could forever dominate the others. When the portfolio manager is deciding the rebalancing rules, he/she should also take the economic environment into consideration. Sometimes, accurate insight about the future global market is pretty necessary.

Lastly, rebalancing too often might not help to increase the portfolio value. On the contrary, it is highly likely to eat the profit that was earned previously.

3.2 Rebalance with Risk Parity

Risk parity definition is proposed by Edward Qian in 2005.Risk parity strategy determines asset weights proportional to the inverse of variance or volatility. Compared with traditional asset allocation strategy, risk parity strategy aims to get higher risk adjusted return and decrease concentration on equities which have high variance/volatility.In the project, asset return volatility is used as risk measurement.

3.2.1 Risk parity rebalancing rules

- Asset volatility and covariance calculation
  The project uses the data before January 2005 as train set and the left data as test set.We used the train set data to get the initial covariance matrix and volatility.Then we set the rolling window length as two years and calculate the rolling volatility($\sigma_i, i \in [1,2,3,4)$ and covariance matrix(Σ) which would be used to calculate portfolio volatility.

- Portfolio volatility calculation
  The reference portfolio has four assets where the weight of asset i is $w_i.w$ is a 4×1 vector defined as $[w_1, w_2, w_3, w4]^T$.The volatility of the portfolio is defined as
  $$\sigma_p = \sqrt{w'\Sigma w} \tag{3.1}$$

- Marginal Risk Contribution of each asset calculation
  Then using the w_i, Σ and σ_p the margin risk contribution of asset i is defined as
  $$\sigma_i(w) = \frac{w_i(\Sigma w)_i}{\sqrt{w'\Sigma w}} \tag{3.2}$$
  $$RC_i = \frac{\sigma_i(w)}{\sigma_p} \tag{3.3}$$
  Based on the equation above,we can get the equilibrium below:
  $$\sum RC_i = 1 \tag{3.4}$$

- Rebalancing with equal marginal risk contribution
  In the project,the risk parity rebalancing rule is to rebalance the portfolio monthly, quarterly and annually by making the marginal risk contribution of the four assets equal from 2005 and 2017.In order to make the risk parity results comparable with the results from section 3.1,leverage is not taken into consideration.For example, if the risk parity rebalancing frequency is set as one month,the four asset weights in the portfolio are calculated at the beginning of each month using the last month data.Then the portfolio return is updated using this month data by keeping the the four asset weights constant.Then we repeated this process for next month.

- Asset Weights Optimization
  In order to get calculate monthly rebalanced asset weights,we would like set $RC_i = \frac{1}{4}$.Then given the equations above, we set the objective function and constraints are defined as following:

$$argmin(w) \sum_{i=1}^{N=4} (w_i - \frac{\sigma_p^2}{N(\Sigma w)_i})^2 s.t. w_i \geq 0, i \in [1,2,3,4] \tag{3.5}$$

  In the project,Python Scipy package is applied.When we get the optimal w^* we scaled w^* as $w^{**}$to make sure $\sum w^{**} = 1$.

3.2.2 Empirical results

We calculate the return volatility for each asset, the three stock ETF volatility rise sharply in 2008 and reached their highest value in June, 2006.Then the volatility decreases after that.And the covariance matrix of the four assets varies from 2005 to 2015.And the covariance between MSCI emerging market Index and MSCI developed market Index in 2010 is larger than the covariance value in 2005 or 2015.

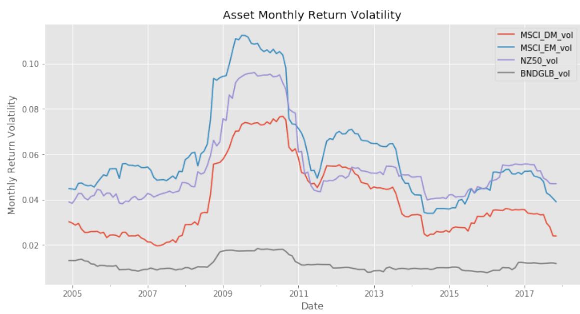

Figure 3.5: Asset Monthly Return Volatility

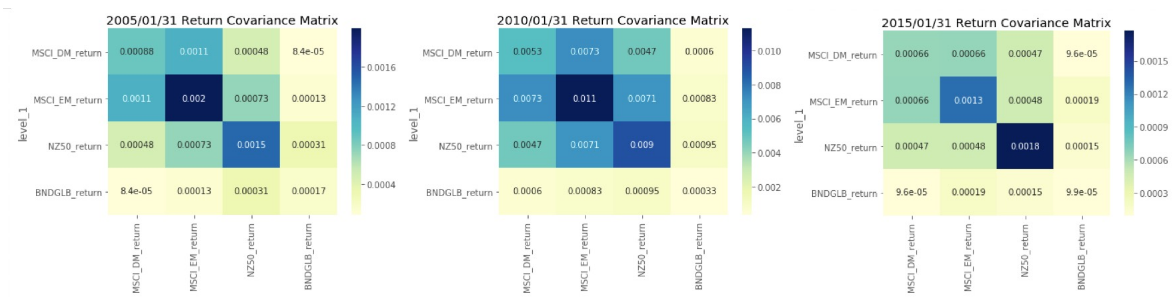

Figure 3.6: Asset Return (Covariance matrix)

Using the marginal risk contribution formulas above, using the asset weights in the reference portfolio, we could get the initial marginal risk contribution of each asset. We can see the equity risk accounts for more than 96 % of the total risk, which is higher than their weight 80 %.

Component ETF	Risk Contribution
MSCI_DM	76.18%
MSCI_EM	15.73%
NZ50	4.26%
BNDGLB	3.83%

Figure 3.7: Reference Portfolio Marginal Risk Contribution

Based in the methods in the above, we calculate the rebalanced portfolio return by monthly, quarterly and annually.The cumulative returns are as following.We can find the the benchmark portfolio returns are above all the risk parity portfolios returns before 2008.And the cumulative returns by annually rebalancing and monthly rebalancing have the similar trend while the cumulative returns by annually rebalancing are a bit higher than the cumulative returns.However,after 2008, the risk parity portfolio returns by annually rebalancing and monthly rebalancing are higher than the benchmark returns. In the end of 2017, the gaps between the benchmark portfolio cumulative returns and the risk parity portfolio cumulative return by annually rebalancing and monthly rebalancing are becoming smaller.But the quarterly-rebalancing risk parity cumulative return are lower than the benchmark returns for all the periods.

Figure 3.8: Risk Parity Cumulative Return

At the same time, we analyze the asset allocation in monthly-rebalanced risk parity portfolio and annually-rebalanced risk parity portfolio.We find the asset weights by monthly-rebalancing are very volatile compared with the weights by annually-rebalanced while they share the similar trend.

	Risk Parity (Volatility)(Monthly)	Risk Parity (Volatility)(Quarterly)	Risk Parity (Volatility)(Annually)
MSCI(DM)	16.70%	17.32%	16.09%
MCSI(EM)	9.94%	11.09%	9.48%
NZ50	10.39%	10.56%	11.02%
BNDGLB	62.97%	61.03%	63.41%

Figure 3.9: Risk Parity Portfolio Asset Allocation)

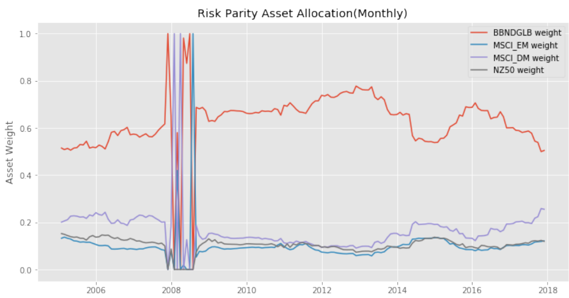

Figure 3.10: Risk Parity Asset Allocation(Monthly)

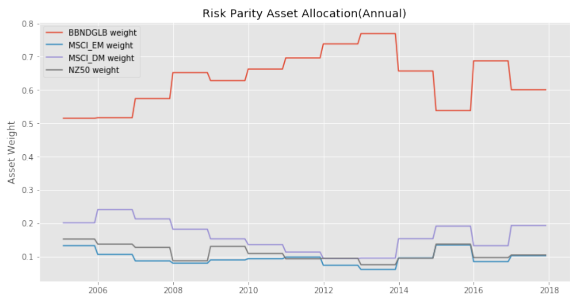

Figure 3.11: Risk Parity Asset Allocation(Annual)

We thought two reasons explained the above.Firstly,the risk parity portfolio has higher weight in bond ETF. After 2008, That the bond prices rise leads to the high bond ETF value. Compared with the reference portfolio, the high weights in bond ETF contributed to the high cumulative return in risk parity strategy. Secondly,Monthly-rebalancing risk parity strategy captures the short-run shocks well while the annually-rebalancing risk parity strategy captures the long-run shocks. And taking holding cost and transaction cost into consideration, it could be explained why the annually-rebalancing has the highest cumulative return.

Risk parity rebalance strategy could be improved in many ways. There are many different ways to measure portfolio risk. In the project,standard deviation of portfolio return is used as total risk measurement while VaR(value-at-risk) or Expected Shortfall is used as total risk measurement in some risk parity strategy.Because either VaR or Expected Shortfall could capture the tail risk better than the standard deviation.In the future we could apply VaR or Expected Shortfall in risk parity rebalancing strategy and compare its performance with the others.At the same time, leverage is not considered in the project in order to get comparable results with others.In the future, we need to add leverage and corresponding borrowing cost and borrowing limit to recalculate the rebalancing performance.

Chapter 4

Investment Strategy with Dynamic Factors

In this section, we would like to purpose an approach to slightly adjust asset weights from initial weights for each re-balancing period, to obtain an advantage in returns compared to the reference portfolio. Each time when we re-balance our portfolio, we at first calculate the risk premium of each factor by Cross-Sectional regression, then we select to adjust the exposure to the factor which has the biggest risk premium in absolute value, next, we find out by Time-Series regression the asset which has the biggest exposure in absolute value to this factor, at last, we adjust the weight of this asset in our portfolio. We assume that, by "profiting" the risk premium, the portfolio performance could be improved. More detail about this strategy would be discussed in the sub-section Investment Strategy.

4.1 Candidate Assets

In addition to the four assets in the reference portfolio, we would consider more candidate assets. Sometimes, other assets may have bigger exposure to certain particular factors than the four assets. Therefore, the more complete our assets pool is, the better our strategy performance would be.

- Equity:
  Related to Size and Momentum Factors: Ken French's 25 Portfolios Formed Monthly on Size and Momentum.
  Related to Market Factor: : S&P500 (investable through ETF)
- Bonds:
  Related to Interest Rate Factor:

SHY: iShares 1-3 Year Treasury Bond ETF
IEF: iShares 7-10 Year Treasury Bond ETF
TLT: iShares 20+ Year Treasury Bond ETF
Related to Credit Rating Factor:
LQD: iShares Investment Grade Corporate Bond
BRHYX: BlackRock High Yield Bond

4.2 Dynamic Exposures Strategy

For each re-balancing period, we conduct the following steps to decide the new target weights in our rebalanced portfolio:

- Normalize each factor by its mean and standard deviation.
- Set initial target weights equal to the reference portfolio.
- Conduct Time-Series Regression of each asset's return onto all the factors and estimate its exposures ('beta') with respect to each factor.
- Conduct Cross-Sectional Regression of the original 4 assets' expected returns onto their exposures with respect to each factor from previous analysis
- Based on the Cross-Sectional Regression results, determine the factor which has the biggest coefficient in absolute value. We label it as the dominant factor for the current re-balancing period. The coefficient in the regression could be interpreted as risk premium, and both positive and negative premiums could be profited by adjusting exposure to them. In this strategy, we would like to only profit the most significant risk premium in absolute value.
- Look back the Time-Series Regression results, determine the asset which has the largest exposure in absolute value to the dominant factor. We add 1% to the target weight of this asset if its exposure has the same sign as the risk premium of the dominant factor. Otherwise, we reduce 1% weight.

To be as clear as possible, we would like to show an example about how we obtain the target weights for one specific re-balancing period. After completing the first four steps, we would have a look at the result of the Cross-Sectional Regression, and we could find that Bullish Sentiment Factor has the biggest risk premium in absolute value.

	Risk Premium
Mkt-RF	0.188287
SMB	0.150695
HML	0.035982
RMW	0.059902
CMA	0.303262
T10Y2Y	-0.182551
Bullish Sentiment	-0.416608
Credit Spread	0.049713
Inflation	0.175942
VIX	-0.101405

Figure 4.1: Cross-Sectional Regression Coefficients

Next, we look back the result of the Time-Series Regression, and we could find that the 30th asset (TLT: iShares 20+ Year Treasury Bond ETF) has the biggest exposure to this factor in absolute value. Since the sign of the risk premium (negative) is the same as the sign of the exposure (negative), we would add 1% to the target weight of TLT. The re-balanced portfolio would contain five assets: four original assets (MSCI(DM), MCSI(EM), NZ50, BNDGLB and TLT), and the updated target weights would be respectively (65-1/4)%, (10-1/4)%, (5-1/4)%, (20-1/4)%, 1%.

Portfolio	const	Mkt-RF	SMB	HML	RMW	CMA	T10Y2Y	Bullish Sentiment	Credit Spread	Inflation	VIX
1	0.0063	0.0027	-0.0192	-0.0147	-0.0420	0.0008	0.8581	-0.2706	0.3606	-0.0492	-0.4663
2	0.0095	0.0121	-0.0158	-0.0155	-0.0400	-0.0072	0.8504	-0.2667	0.3629	-0.0489	-0.4609
3	0.0112	-0.0096	-0.0213	-0.0134	-0.0468	0.0042	0.8619	-0.2737	0.3619	-0.0460	-0.4667
4	0.0036	-0.0338	-0.0173	-0.0167	-0.0406	0.0036	0.8602	-0.2743	0.3582	-0.0499	-0.4622
5	0.0113	0.0107	0.0071	-0.0005	-0.0545	-0.0036	0.8572	-0.2658	0.3765	-0.0469	-0.4638
6	0.0104	0.0012	0.0082	-0.0067	-0.0437	-0.0008	0.8608	-0.2715	0.3622	-0.0488	-0.4652
7	0.0122	-0.0028	0.0063	-0.0091	-0.0427	0.0011	0.8615	-0.2735	0.3561	-0.0501	-0.4646
8	0.0136	-0.0055	0.0066	-0.0136	-0.0432	0.0043	0.8605	-0.2725	0.3588	-0.0494	-0.4666
9	0.0111	-0.0003	0.0110	-0.0194	-0.0443	0.0044	0.8606	-0.2718	0.3555	-0.0515	-0.4672
10	0.0130	0.0215	0.0056	0.0013	-0.0476	-0.0032	0.8542	-0.2694	0.3758	-0.0467	-0.4575
11	0.0142	0.0087	0.0062	-0.0069	-0.0408	-0.0014	0.8574	-0.2732	0.3645	-0.0480	-0.4620
12	0.0126	0.0012	0.0054	-0.0107	-0.0411	0.0008	0.8576	-0.2739	0.3605	-0.0480	-0.4638
13	0.0123	-0.0011	0.0080	-0.0123	-0.0413	0.0005	0.8593	-0.2741	0.3557	-0.0482	-0.4618
14	0.0110	0.0039	0.0109	-0.0211	-0.0433	0.0028	0.8612	-0.2757	0.3494	-0.0510	-0.4621
15	0.0114	0.0160	-0.0026	-0.0015	-0.0470	0.0015	0.8549	-0.2669	0.3762	-0.0453	-0.4629
16	0.0131	0.0081	-0.0033	-0.0094	-0.0412	0.0006	0.8589	-0.2707	0.3652	-0.0468	-0.4643
17	0.0123	0.0047	0.0001	-0.0108	-0.0400	-0.0005	0.8593	-0.2741	0.3590	-0.0477	-0.4617
18	0.0106	0.0030	0.0024	-0.0139	-0.0383	0.0016	0.8598	-0.2751	0.3542	-0.0478	-0.4603
19	0.0107	0.0028	0.0063	-0.0238	-0.0396	0.0028	0.8593	-0.2739	0.3532	-0.0492	-0.4672
20	0.0092	0.0194	-0.0094	-0.0007	-0.0469	-0.0014	0.8580	-0.2677	0.3709	-0.0472	-0.4617
21	0.0116	0.0079	-0.0096	-0.0106	-0.0426	0.0012	0.8581	-0.2697	0.3683	-0.0457	-0.4673
22	0.0132	0.0033	-0.0077	-0.0137	-0.0413	0.0013	0.8606	-0.2734	0.3615	-0.0475	-0.4647
23	0.0115	-0.0001	-0.0066	-0.0187	-0.0393	0.0037	0.8596	-0.2726	0.3580	-0.0482	-0.4657
24	0.0101	0.0016	-0.0019	-0.0259	-0.0406	0.0025	0.8623	-0.2736	0.3545	-0.0489	-0.4714
25	0.0067	0.0242	-0.0267	0.0011	-0.0501	-0.0049	0.8562	-0.2693	0.3606	-0.0437	-0.4530
26	0.0098	0.0074	-0.0197	-0.0053	-0.0436	0.0006	0.8583	-0.2730	0.3613	-0.0480	-0.4589
27	0.0099	0.0024	-0.0183	-0.0096	-0.0384	0.0015	0.8587	-0.2742	0.3620	-0.0478	-0.4631
28	0.0089	0.0009	-0.0157	-0.0174	-0.0394	0.0044	0.8593	-0.2759	0.3560	-0.0486	-0.4629
29	0.0092	0.0021	-0.0115	-0.0256	-0.0396	0.0026	0.8606	-0.2740	0.3498	-0.0503	-0.4621
30	0.0013	-0.0378	-0.0177	-0.0175	-0.0398	0.0046	0.8605	-0.2761	0.3544	-0.0500	-0.4593
31	0.0026	-0.0404	-0.0202	-0.0180	-0.0383	0.0061	0.8601	-0.2783	0.3499	-0.0543	-0.4549
32	0.0001	-0.0376	-0.0152	-0.0152	-0.0411	0.0031	0.8605	-0.2740	0.3570	-0.0487	-0.4629
33	0.0007	-0.0309	-0.0184	-0.0166	-0.0408	0.0032	0.8607	-0.2744	0.3640	-0.0514	-0.4674
34	0.0010	-0.0213	-0.0145	-0.0145	-0.0410	-0.0001	0.8625	-0.2729	0.3629	-0.0474	-0.4695
35	0.0069	0.0028	-0.0178	-0.0148	-0.0402	0.0031	0.8596	-0.2736	0.3567	-0.0490	-0.4633

Figure 4.2: Time-Series Regression Coefficients

4.3 Empirical Results

First of all, we would like to specify the category of new candidate assets used when we calculate costs:

- Ken French's 25 Portfolios Formed Monthly on Size and Momentum: Equity Momentum (e.g. WML)

- S&P500: U.S. Large Cap Equity
- iShares 1-3 Year Treasury Bond ETF (SHY): US Government Bonds
- iShares 7-10 Year Treasury Bond ETF (IEF): US Government Bonds
- iShares 20+ Year Treasury Bond ETF (TLT): US Government Bonds
- iShares Investment Grade Corporate Bond (LQD): US High Grade Credit
- BlackRock High Yield Bond (BRHYX): US Speculative Credit

As the strategy in this section needs training dataset for regression, we set January 2005 as the date when we start to implement our strategy. In the following figure, the difference between the cumulative returns of dynamic exposures strategy and that of the reference portfolio is calculated. The re-balancing frequency for our strategy is set to be every 12 months in this example, while the re-balancing frequency for the reference portfolio is every 3 months. We could see that, our strategy has at first a worse performance from 2005 to 2009, then a better performance since 2009.

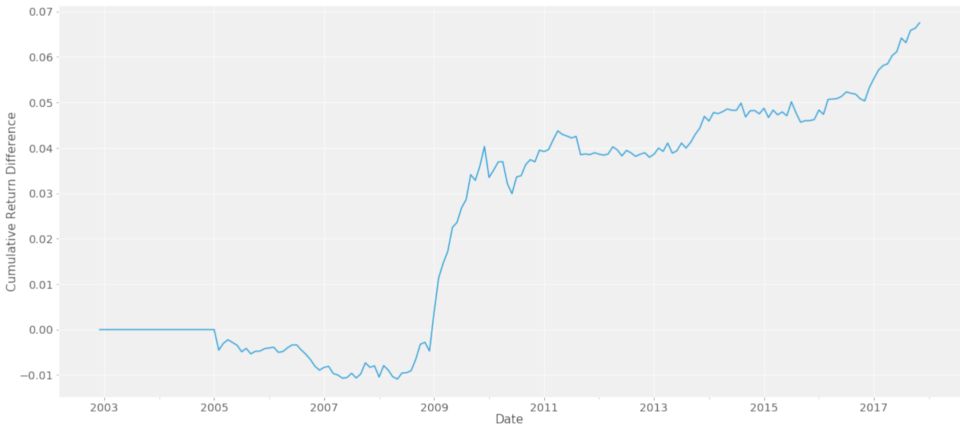

Figure 4.3: Cumulative Return Difference: Adjusted Portfolio (Re-balancing Frequency: 12M) minus Reference Portfolio (Re-balancing Frequency: 3M)

The following plot is a summary of asset value weights varying over time. Apart from the four original assets, TLT and BRHYX have been included into the portfolio. From 2005 to 2007, at each date of re-balancing, the dominant factor is Inflation whose risk premium is negative, which means that the price of Inflation risk is negative. This result is reasonable, since financial assets' prices continually increased during that period and inflation risk was undervalued (inflation uncertainty was low). Thus, we should "short" this risk. TLT is the index with the biggest negative exposure to Inflation, which means that, to "short" Inflation risk, the most effective way is to buy long-term bonds. 1% would be added to the target weight of TLT.

From 2008 to 2011, the dominant factor is T10Y2Y whose risk premium is negative. Term spread has been a good proxy for the bond risk premium. During financial crisis, the bond risk premium could be negative, since more investors would buy bonds to hedge against equity risk, which would drive up bonds prices and therefore drive down risk premiums. BRHYX has the biggest positive exposure to T10Y2Y, so we should short 1% BRHYX.

From 2012 to 2016, the dominant factor is Bullish Sentiment whose risk premium is negative, as the market has been recovering and Bullish Sentiment has been undervalued. TLT has the biggest negative exposure to the dominant factor. Thus, 1% would be added to the target weight of TLT.

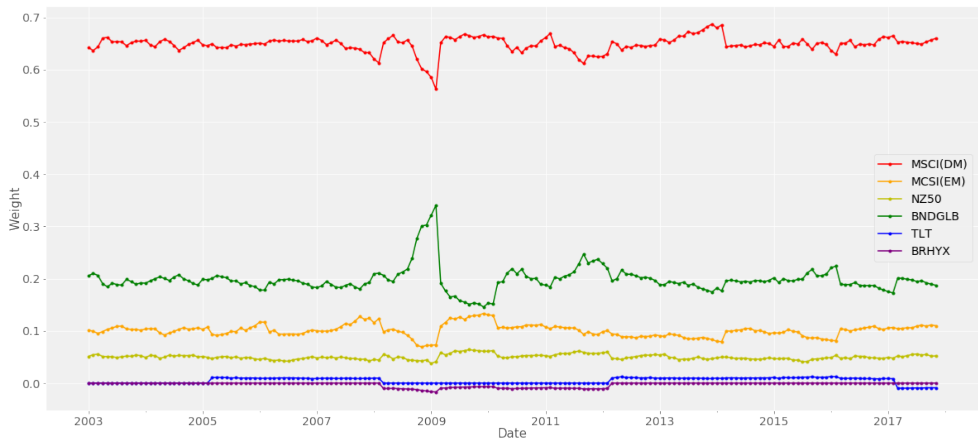

Figure 4.4: Asset Value Weights Varying Over time

From the following figure, we could see that, the dynamic exposures strategy best performs when the re-balancing frequency is set to be 12 months or 15 months. If we apply a higher or lower frequency, then a lower cumulative return would be obtained. For each re-balancing period, the dominant factor selected reflects the economic picture. Thus, the re-balancing frequency should be consistent with the length of an economic cycle which should not be too short or too long.

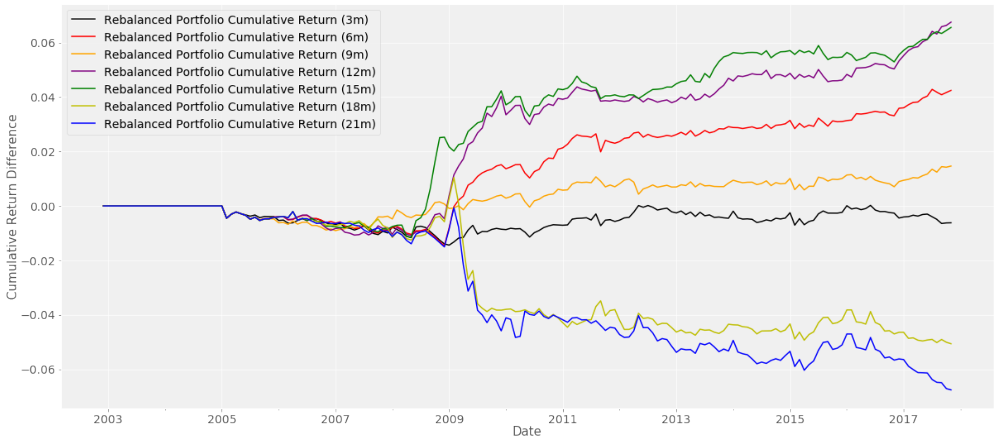

Figure 4.5: Cumulative Return Difference for Different Re-balancing Frequencies

Chapter 5

Evaluation for Investment Strategies

In this study, we mainly applied four metrics to evaluate those investment strategies explored previously. Those metrics are the cumulative return on the last observation day, the annual mean return, the annual variance and the annualized Sharp Ratio.

	Annual Mean Return	Cumulative Return	Annual Variance	Sharpe Ratio
No Rebalancing	0.053817	1.795579	0.183515	0.435183
Target Weights(Monthly)	0.055604	1.834637	0.186067	0.446541
Target Weights(Quarterly)	0.056051	1.846135	0.185061	0.451357
Target Weights(Annually)	0.057946	1.896745	0.180034	0.473086
Target Weights(5% Threshold)	0.058203	1.889941	0.192354	0.459714
Target Weights(10% Threshold)	0.052968	1.776088	0.183740	0.428055
Target Weights(15% Threshold)	0.052968	1.776088	0.183740	0.428055
Target Weights(5% Threshold)	0.058203	1.889941	0.192354	0.459714
Target Weights(10% Threshold)	0.052968	1.776088	0.183740	0.428055
Target Weights(15% Threshold)	0.052968	1.776088	0.183740	0.428055
Risk Parity (Volatility)(Monthly)	0.052067	1.882561	0.005325	0.713527
Risk Parity (Volatility)(Quarterly)	0.036528	1.511780	0.008211	0.403114
Risk Parity (Volatility)(Annually)	0.052648	1.902014	0.004896	0.752443
Dynamic Exposures Strategy	0.144100	2.862609	0.079900	0.509900

Figure 5.1: Strategy Performance

The reference rebalancing rule selected in this paper is to rebalance with target weights on a quarterly basis. Its performance is pretty moderate. The average annual return is 5.61%, the cumulative return is 184.61%, the annual variance is 0.1851 and the sharp ratio is 0.4514.

From this table, we could observe that the dynamic exposure strategy gets the highest average annual return, which is 14.41%. The highest cumulative return, 286.26%, is also earned by this strategy. Meanwhile, for the annual variance, the lowest variance and the highest sharp ratio come from the risk parity strategy with annual rebalancing. They are 0.004896 and 0.752443 respectively.

From the result, we could conclude that, in terms of average annual return and cumulative return, the dynamic exposure strategy performs the best among all strategies. In terms of the sharp ratio, the risk parity strategy rebalanced annually dominates all the rest strategies.

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