

**INVESTING IN GLOBAL EXCHANGE-TRADED FUNDS: A RISK PARITY
APPLICATION**

by

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Abstract

In this paper, I examine the use of Risk Parity for enhancing performance in the portfolio constituted of Global Exchange-Traded Funds across nine asset classes. The study is supported by two sample periods. In the first sample period from September 2008 to October 2016, Unlevered Risk Parity strategy is compared with two benchmark strategies on risk-adjusted returns. In the second sample period, 2011- 2016, other two Levered Risk Parity portfolios that have different construction principles are added into comparison to analyze the influence of leverage in Risk Parity strategy. The results show that Risk Parity strategy do enhance the portfolio performance with higher Sharpe ratio and lower annualized standard deviation, but I have also found that the performance of trading strategy is sensitive to the selected sample periods. And the use of leverage in Risk Parity strategy has increased cumulative returns and remained a comparably high Sharpe ratio.

Keywords: Risk Parity; Exchange-Traded Funds; Diversification; Equal Risk Contribution; Correlation and Leverage.

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Table of Contents

Approval.....	ii
Abstract.....	iii
Acknowledgements.....	iv
Table of Contents.....	v
List of Figures.....	vi
List of Tables.....	vii
1: Introduction.....	1
2: Literature Review.....	3
3: Data and Methodology.....	6
3.1 Data.....	6
3.2 Methodology.....	7
3.2.1 Equal-Weighted Portfolio.....	7
3.2.2 Naïve Risk Parity Portfolio.....	8
3.2.3 Unlevered Risk Parity Portfolio.....	8
3.2.4 Levered Risk Parity Portfolio.....	10
4: Results and Analysis.....	12
4.1 Performance Evaluation of the first sample period.....	12
4.2 Performance Evaluation of the second sample period.....	17
5: Conclusion.....	19
Reference List.....	20

List of Figures

Figure 1: Asset Volatilities	7
Figure 2: Cumulative performance of three portfolios	13
Figure 3: 3-Month Rolling Standard Deviation (Annualized)	13
Figure 4: 3-Month rolling average correlation across all asset classes	15
Figure 5: Gross weight allocation for the unlevered Risk Parity portfolio	16
Figure 6: Cumulative returns (non-annualized) for five strategies from Feb 2010 to Oct 2016	17

List of Tables

Table 1: Dataset	6
Table 2: Statistical comparison summary for three strategies (September 2008 to October 2016).....	14
Table 3: Summary of Average Monthly Return and Annualized Sharpe Ratio for each year of the sample period*	15
Table 4: Statistical comparison summary for five strategies (Feb-2010 to Oct-2016).....	17

1: Introduction

Asset allocation plays a major role in the returns of the investment portfolio as different asset class performs differently even under the same market condition. However, correlations between asset returns are not perfect and could change dynamically, which means that diversification becomes a useful tool to reduce the overall portfolio risk if optimal weights are assigned to the investment portfolio.

Markowitz's (1952) Modern Portfolio Theory introduces a new idea to construct the investment portfolio that balances its risk and return, which means that risk-aversion investors could get the maximum return for any given level of risk. In his theory, diversification is realized when some little or negative correlated assets are combined. Based on Markowitz's work, Tobin (1958) and others improved the "efficient frontier" by adding risk-free assets to the total portfolio, which also makes leveraging a well-diversified portfolio possible. These portfolio construction framework and diversification technique have worked well for several decades, but as they are focusing on dollar allocation diversification, a natural question to ask is whether it is a true diversification or just a trade-off between risk and return.

Many studies have attempted to allocate asset weights on a risk basis, and there are many products developed by fund managers to achieve true diversification. Many of these come under the same concept, "Risk Parity", which has similarities with Modern Portfolio Theory but emphasizes on risk-based diversification. As a new asset allocation technique, Risk Parity strategy takes equal risk contribution in each constituent of the portfolio and it is widely used by investment institutions. The first Risk Parity Fund called All Weather Fund, was pioneered in 1996, and the theory of Risk Parity is later proposed by Qian (2005).

As Risk Management becomes more and more important in investments nowadays, I think it would be useful if we can realize true diversification with Risk Parity and thus reduce the overall portfolio risk in an ex-ante way. Therefore in this paper, I follow Mulrane's (2014) idea of applying Risk Parity plan to Exchanged-Traded Funds but extend the analysis to a much more sophisticated weighting scheme that considers asset correlations and also present two different methods to construct the levered Risk Parity portfolios. My study is based on an ETF portfolio because of two reasons. Firstly, It's easier to build a global portfolio with ETFs and secondly,

with the popularity of ETFs, Risk Parity strategy in ETFs can be used by more investors, both individually and institutionally. To examine the use of risk parity for enhancing performance in the context of a global ETFs portfolio, Equal-Weighted strategy and Naïve Risk Parity strategy, which has the idea of risk diversification but ignores correlations, are used as the benchmarks in this paper. My results show that in the sample period from September 2008 to October 2016, Unlevered Risk Parity outperforms both Equal-weighted and Naïve Risk Parity on cumulative returns and risk-adjusted returns, which is measured by Sharpe Ratio. In the sample period starting from February 2010 to October 2016 when two levered Risk Parity strategies are added into comparisons, 1.5X levered Risk Parity using borrowing money has highest annualized returns and comparably high Sharpe Ratio. But the 1.2X levered Risk Parity portfolio performs not well and even worse than the unleveraged one because of its relatively higher volatilities.

The remainder of this paper is organized as follows. Section 2 provides a brief review of the related literature on the portfolio theory and Risk Parity Strategy. Section 3 describes the data and methodologies that are used to construct five investment strategies in this paper. Section 4 discusses the results of different strategies on two sample periods and provides analysis for the portfolio performances. Finally, section 5 concludes the paper with a summary and discussion of related further studies.

2: Literature Review

The seminal work in Portfolio Theory is Markowitz (1952). He introduces the concept of an efficient frontier that can be constructed using the portfolio assets' mean and variance and balances its risk and return characteristics. Modern Portfolio Theory (MPT, henceforth) has been criticized when applied to practice, for instance, the estimated risk and return are based on expected return. Also, the minimum variance portfolios are not well diversified as they are always concentrated in a few low-volatility assets. The Post-Modern Portfolio Theory (PMPT, henceforth, Rom and Ferguson, 1993) is an extension of Markowitz's MPT but measures the risk using internal rate of return. The essential difference between these two theories is that PMPT focuses on the downside risk that uses the standard deviation of negative return while MPT measures the total risk.

Both MPT and PMPT provide the way of asset-based diversification, which means that if more little or negative correlated assets are added to the portfolio, more diversified it will be and as well as less risky. Maximum Diversification Theory (Chouefaty and Coignard, 2008) measures the portfolio diversification from the perspective of risk, which takes the asset volatilities as a criterion for asset allocation. Chouefaty and Coignard define the diversification ratio in their paper as the weighted average of volatilities divided by the portfolio volatilities. Portfolio weights are chosen to maximize diversification ratio and then create the most diversified portfolio.

Have the same concept as Maximum Diversification Theory that focuses on risk-based diversification, Risk Parity approach (Qian 2005, Maillard, Roncalli and Teiletche 2010) constructs portfolio on predicted risk, without expected returns. The principles of Risk Parity are applied differently according to different investment styles and trading strategies. In this paper, I am focusing on the Equal Risk Contribution portfolio, one of the most well-known versions of Risk Parity. In the Equal Risk Contribution portfolio, each asset class contributes in the same way to the overall portfolio volatility, which is equal to have the same marginal risk contribution of each asset class.

Derived from Modern Portfolio Theory, Risk Parity (RP, henceforth) approach has the same theoretical basis as MPT. Markowitz (1999) states that the variance of the overall portfolio

can be expressed as the function of variances and covariances of the individual securities comprising the portfolio. Based on this, Maillard, Roncalli and Teiletche (2010) show that the risk of the portfolio can be seen as the sum of the risk contribution of each asset class (see more in Section 3) and propose an approach to solving the optimization problem with Sequential Quadratic Programming algorithm. To address the equation of portfolio weights that equalize the total risk contribution of each asset class, Chaves, Hsu, Li and Shakernia (2012) extend the previous work further and present two algorithms. The first one is Newton's method that rewrites the nonlinear equation as a linear approximation with Taylor expansion and finds the root. The second one is Power method that starts with an initial guess of weights. As the weights are a function of asset betas, which in turn depend on the weights, Power Method solve the circular relationship by repeating steps to satisfy the condition. Furthermore, Daly, Rossi and Herzog (2012) provide a relatively convenient way to implement the risk parity framework in the cost function to solve the optimization problem. I use this method to construct the risk parity portfolio in the paper, and more details are shown in the next section.

Several empirical studies have proved the competitiveness of the Risk Parity strategy. Anderson, Bianchi and Goldberg (2012) compare unlevered and levered risk parity with value-weighted and 60/40 mix investment strategies over the 85-year horizon (1926-2010) based on US Equity and US Treasury Bond. They find that the strategy performance depends materially on the analysis period. Levered risk parity strategy returns substantially more than other three strategies by risk-adjusted return, Sharpe ratio, but it underperforms at the Post-War sample (1946-1982). Chaves, Hsu, Li and Shakernia (2011) state the similar conclusion that risk parity portfolio doesn't consistently outperform a simple Equal-Weighted portfolio and it is very sensitive to the asset classes. But they do show that risk parity strategy has a higher Sharpe ratio than well-established Mean-Variance portfolio over a 30-year dataset of US stocks and bonds. Baltas (2015) uses the Risk-Parity principle in constructing a long-short trend-following strategy with 35 future contracts as the traditional trend-following strategy is less attractive in the post-crisis period. The backtesting shows that the approach does enhance the performance as the Sharpe ratio doubles over the post-crisis period and it is primarily driven by the surges of pairwise correlations across asset classes. Stagnol (2016) applies the risk parity principle for the case of Corporate Bond index using Duration Times spread. The findings show that Equal Risk Contribution principle is clearly a defensive strategy as the volatility and drawdown of the portfolio are noticeably reduced, and the risk-adjusted returns are equal or above the benchmark.

There are several studies that relate to the characteristics of Risk Parity strategy. Qian (2012) states that the diversification returns of leveraged portfolios can be decomposed into two parts, which are positive ones from rebalancing and negative ones caused by the leverage of the overall portfolio. And the diversification return is expected to rise as more assets are added to the portfolios. Asness, Frazzini and Pedersen (2012) demonstrate that Risk Parity portfolio overweights safer assets that offer higher risk-adjusted returns and thus create the opportunities to use leverage. However, Anderson, Bianchi and Goldberg (2013) question the use of leverage in risk parity portfolio as the Fed-supported interest rates are higher after the post-crisis period and the cost of funding a levered strategy will be higher.

3: Data and Methodology

3.1 Data

To construct a global exchanged-traded fund portfolio, I use Yahoo Finance daily closing prices of 10 ETFs across different asset classes. The list of the asset classes and exchange-traded fund are presented in Table 1.

Table 1: Dataset

Asset class	Index	Ticker
Fixed Income	ICE U.S. Treasury 7-10 Year Bond Index	IEF/UST*
Currency	DB G10 Currency Future Harvest Index	DBV
Energy	S&P Global 1200 Energy Sector Index	IXC
US Equity	CRSP US Total Market Index	VTI
Precious metals	DBIQ Optimum Yield Precious Metals Index Total Return	DBP
Developed Market Equity	MSCI EAFE Index	EFA
Emerging Market Equity	FTSE Emerging Markets All Cap China A inclusion Index	VWO
Agriculture	DBIQ Diversified Agriculture Index Excess Return	DBA
Global Real Estate	DJ Global Select Real Estate Securities Index	RWO

Note: UST is a 2X leveraged ETF that tracks the same index as IEF, and it is only used to construct the levered Risk Parity portfolio in this paper.

All the daily closing prices of 10 ETFs are downloaded from www.yahoofinance.com. And the Secondary Market Rate of 3-Month Treasury Bill is used as the risk-free rate when calculating the Sharpe ratio and as the borrowing cost when constructing the levered Risk Parity portfolio. The monthly T-bill rate is downloaded from an online database of the Federal Reserve Bank of St. Louis. The first sample period in this paper is starting from June 2008 to October 2016 when all ETFs are traded. The second sample period is starting from February 2010 to

October 2016 when leveraged ETF is used to construct the levered Risk Parity Portfolio as the leveraged ETF (UST) used in this paper is only traded from the year 2010.

The return of each ETF is calculated with the formula:

$$r_{t,t+1} = \frac{P_{t+1} - P_t}{P_t}$$

where P_t and P_{t+1} denote the ETF price at the month of t and $t+1$.

Figure 1 shows the annualized volatilities of the returns of all the ETFs in the paper. It's obvious that volatilities are dispersed, as Fixed Income exhibits lower volatility while Energy is the most volatile one.

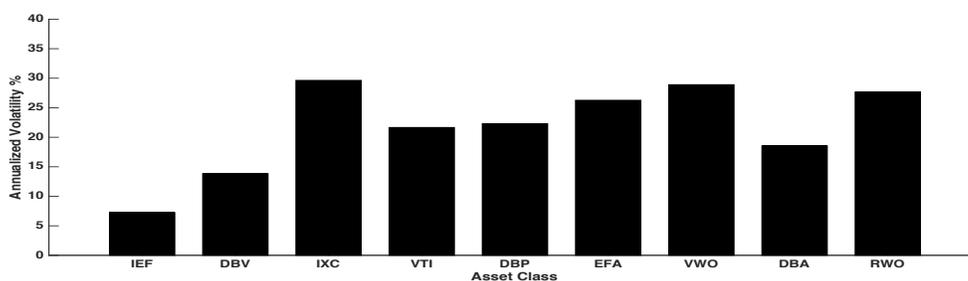


Figure 1: Asset Volatilities

3.2 Methodology

Four trading strategies are used to construct portfolios in this paper, and the four portfolios are Equal Weighted portfolio, which is used as the benchmark, Naïve Risk Parity portfolio, Unlevered Risk Parity portfolio and Levered Risk Parity portfolio. And I use two different methods to construct the levered Risk Parity portfolio. Therefore, there are five different investment portfolios in this paper.

3.2.1 Equal-Weighted Portfolio

It's a quite straightforward way to construct the equal weighted portfolio, as the formula shows:

$$\forall(i, j) w_i = w_j = \frac{1}{N}$$

Each asset class has the same value weight in the trading period, which is $1/9$ in this paper. The portfolio is rebalanced monthly to reallocate value among the asset classes.

3.2.2 Naïve Risk Parity Portfolio

Naïve risk parity is the simplest way to allocate asset weights by risk. It can be called inverse-volatility scheme as the asset weightings are inversely proportional to their volatilities:

$$\forall i \quad w_i = \frac{\frac{1}{\sigma_i}}{\sum_{j=1}^N \frac{1}{\sigma_j}} ,$$

where N is the number of the asset classes, σ_i denotes the volatility of asset returns. Correlation is not considered in Naïve Risk Parity strategy, but it can be shown that this scheme can split portfolio volatility equally across all asset classes as long as the correlations are equal, though it is the rare case in reality. In this paper, the portfolio is rebalanced every month and the volatility is estimated using a window of the most recent three-months until the end of each month. Therefore the sample period starts in September 2008.

3.2.3 Unlevered Risk Parity Portfolio

Equal Risk Contribution approach is a popular and well-accepted way to construct real Risk Parity portfolio after accounting for correlations. Denote matrixes w and R the weighting and monthly return of all asset classes in the portfolio, the volatility, and return of the portfolio can be expressed as:

$$\sigma_p = \sqrt{w^T * \Sigma_p * w}$$

$$R_p = \sum_{i=1}^N w^T * R^T$$

Where N is the number of rebalances, $w = [w_1, w_2, \dots, w_9]^T$, $R = [r_1, r_2, \dots, r_9]$, Σ_p is the annualized covariance matrix of asset returns which is recalculated monthly using the most recent 3-months daily returns.

The Marginal Risk Contribution (MRC, henceforth) of the portfolio is defined as the change in the portfolio volatility caused by an infinitesimal change in the weight w_i allocated to it:

$$MRC \stackrel{\text{def}}{=} \frac{\partial \sigma_p}{\partial w_i} = \frac{1}{2\sigma_p} \frac{\partial \sigma_p^2}{\partial w_i}$$

In the formula, the variance is used instead of volatility to make the optimization simplified later. Total Risk Contributed (TRC, henceforth) by each asset class is defined as the product of weight and Marginal Risk Contribution:

$$TRC_i \stackrel{\text{def}}{=} w_i * MRC = \frac{w_k \partial \sigma^2 p}{2\sigma_p \partial w_i}$$

The sum of the Total Risk Contribution of each asset class shows:

$$\begin{aligned} \sum_i TRC_i &= \sum_i w_i MRC_i = \frac{1}{2\sigma_p} \sum_i w_i \frac{\partial w^T \Sigma_p w}{\partial w_i} \\ &= \frac{1}{2\sigma_p} \sum_i 2w^T \Sigma_p e_i w_i = \frac{2w^T \Sigma_p w}{2\sigma_p} = \sigma_p \end{aligned}$$

Where $e_i \stackrel{\text{def}}{=} [0, 0, \dots, 1 \dots 0]^T$ it is a vector with a unit value in the i^{th} position.

The derivation comes to the conclusion that the portfolio risk can be the sum of Total Risk Contribution of each constituent.

As for the Equal Risk Contribution portfolio, each asset class should have the same risk contribution, which means $TRC_i = TRC_j$. The equation is equal to:

$$w_i \frac{\partial \sigma^2 p}{\partial w_i} = w_j \frac{\partial \sigma^2 p}{\partial w_j}$$

When dealing with it in Matlab, Least Square method is used to solve the optimization problem that minimizes differences between all the TRCs, which is expressed as:

$$\begin{aligned} Q(w) &= \sum_{i=1}^N \sum_{j>i}^N (w_i \frac{\partial \sigma^2 p}{\partial w_i} - w_j \frac{\partial \sigma^2 p}{\partial w_j})^2 \\ &= \sum_{i=1}^N \sum_{j>i}^N (w^T \Sigma_p E_{ij} w)^2 \end{aligned}$$

where E_{ij} is defined as the difference between the diagonal matrixes, which is $diag(e_i) - diag(e_j)$. $E_{ij} = diag(e_i) - diag(e_j)$

To construct the Equal-Risk Contribution portfolio, the objective is to find asset weightings w that minimizes the function $Q(w)$. Practically, what I am doing is solving the optimization problem of asset weightings:

$$\begin{aligned} w &= \arg \min_w \left\{ \sum_{i=1}^N \sum_{j>i}^N (w^T \Sigma_p E_{ij} w)^2 \right\} \\ w_i &\geq 0, \sum_i |w_i| = 1 \end{aligned}$$

The Equal-Risk Contribution portfolio is rebalanced every month, which means that I recalculate the covariance matrix of asset returns monthly to have the new weightings of the portfolio. The covariance matrix is estimated using the most recent 3-months daily returns of each asset class. Account for a three-months window for covariance matrix, the sample period starts in September 2008.

3.2.4 Levered Risk Parity Portfolio

The levered Risk Parity portfolio in this paper is constructed at the base of unlevered Risk Parity portfolio, which means I am adjusting the asset weightings on the unlevered Risk Parity portfolio.

In this study, I provide two methods to construct the levered Risk Parity Portfolio. The first one is simply borrowing money at the assumption that one can borrow at the risk-free rate. In section 4, the 1.5X levered RP portfolio is construed in this way. The aggregated leverage ratio for the portfolio is 1.5 and I assume that the additional borrowing money is all invested in other eight asset classes with the same leverage ratio except Fixed Income as it has already overweighted compared with Naïve RP and EW portfolios. So, the value allocated to Fixed Income is the product of initial own funds and the monthly-rebalanced weightings. The value of other eight asset classes is increased as the borrowing money is assigned proportionally to their weights. And the borrowing cost, at the cost of risk-free rate, is paid at the end of each month.

The second method used in this paper is adding the Leveraged Exchange-Traded Fund (UST) to the unlevered Risk Parity Portfolio and the 1.2X levered RP portfolio in section 4 is constructed in this way. UST tracks the same index as IEF but doubles the daily return, which makes leverage possible in this case. To calculate the portfolio weights with 10 asset classes, I follow the equations below:

$$w_{IEF} + w_{DBV} + w_{IXC} + w_{VTI} + w_{DBP} + w_{EFA} + w_{VWO} + w_{DBA} + w_{RWO} = 100\%$$

$$w_{IEF}^* + 2 * w_{UST} + Leverage\ Ratio * (w_{DBV} + w_{IXC} + w_{VTI} + w_{DBP} + w_{EFA} + w_{VWO} + w_{DBA} + w_{RWO}) = 100\%$$

where w_{IEF}^* denotes to the new weight of Fixed Income.

But there is one limitation of this method that the leverage ratio is relatively low if short position is not used and that's why only 1.2X levered portfolio is constructed in section 4. In this study, this method is merely a simple way to construct levered portfolio without borrowing

money. Further study can be extended to include inverse ETFs or leveraged ETFs in other asset classes to have higher leverage ratio.

4: Results and Analysis

In this section, I divide the results and analysis into two parts. In the first part, Unleveraged Risk Parity Portfolio is compared with Equal-Weighted (EW, henceforth) and Naïve Risk Parity portfolios on the sample period starting from September 2008. In the second part, two different levered Risk Parity portfolios are added into the comparison and the sample period is starting from February 2010. The performance of portfolios is analysed from the perspective of risk-adjusted returns.

4.1 Performance Evaluation of the first sample period

Figure 2 and 3 respectively present the cumulative performance and annualized 3-month rolling standard deviation of Equal-weighted, Naïve Risk Parity and Unlevered Risk Parity portfolios in the sample period. It's obvious that Unlevered Risk Parity outperforms other two strategies almost across all the sample period in the perspective of cumulative returns. In previous studies, the empirical evidence usually has the conclusion that Unlevered Risk Parity has higher risk-adjusted return but lower excess return. But in this study, because the sample period starts from the end of the year 2008, which is exactly the financial crisis period, the results are sensitively influenced by the turbulent markets. This is in accordance with the findings of Anderson, Bianchi and Goldberg (2012) that strategy performance depends materially on the analysis period. In Figure 2, when both Naïve Risk Parity and Equal-Weighted portfolios perform poorly at the end of 2008 and the beginning of 2009, Unlevered Risk Parity performs really well. In the year 2011, all three strategies performed so closely and from the end of the year 2013, the performance of these three strategies are relatively stable, which is shown in Figure 2 as they have almost the same trend for a long period. Therefore asset returns will be slightly different. When looking at the volatilities of the portfolio returns, Naïve Risk Parity has much lower volatilities compared with other two approaches, especially in the extreme market conditions when the volatilities of EW portfolio increase dramatically. It can be seen from the graph that at the end of 2008 and 2011, when the volatilities of Equal-Weighted portfolios are approximately 45% and 25%, Unlevered Risk Parity portfolio only has 15% and 8% annualized volatilities.

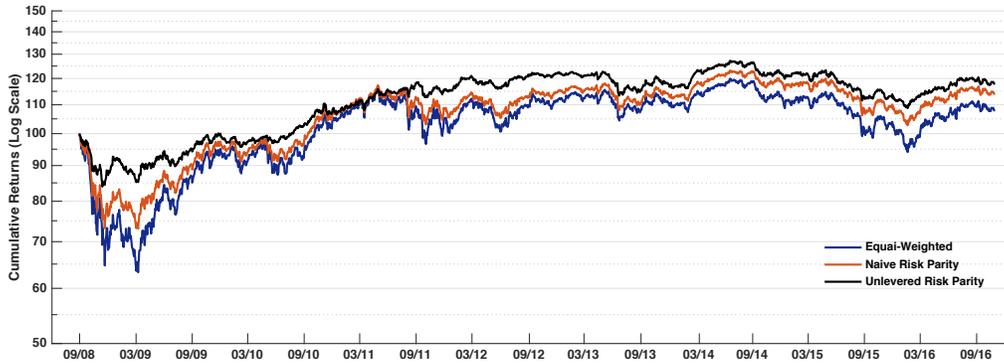


Figure 2: Cumulative performance of three portfolios

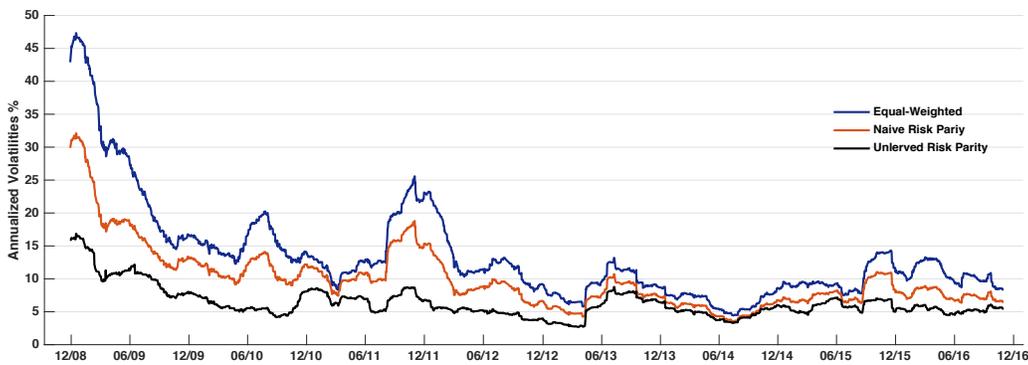


Figure 3: 3-Month Rolling Standard Deviation (Annualized)

Table 2 summarizes the ratios that I have used in this paper to analyse the performance of all the strategies and the ratios are calculated on the whole sample period. The ratios used in this study are focusing on risk-adjusted returns and the downside risk. They are annualized return, annualized standard deviation, annualized Sharpe ratio and maximum drawdown. The results are quite surprising as Unlevered Risk Parity has outperformed EW and Naïve RP in all measurements. The Sharpe ratio of Unlevered Risk Parity portfolio is quite low when compared to a good trading strategy that usually has an above-one Sharpe ratio, but in the sample period, it doubles the Naïve Risk Parity portfolio and is nearly four times higher than the Equal-weighted portfolio because of the higher return and lower volatility. The Maximum Drawdown of Unlevered Risk Parity is only 16.07% while they are 36.73% and 26.91% for Equal-Weighted and Naïve Risk Parity. Max Drawdown measures the largest loss one can suffer when investing in the peak value. Thus, the lower absolute amount of Maximum Drawdown, the safer the investment is.

Table 2: Statistical comparison summary for three strategies (September 2008 to October 2016)

	Equal-Weighted	Naïve Risk Parity	Unlevered Risk Parity
Annualized Return	0.96%	1.63%	2.65%
Annualized Std Dev	15.91%	11.38%	6.91%
Annualized Sharpe ratio ($R_f = 0.12\%$)*	0.0528	0.1327	0.2793
Maximum Drawdown	36.73%	26.91%	16.07%

Note: Risk-free rate used in Sharpe ratio is the average of annual 3-month Treasury Bill rates of the sample period

From the analysis above, it seems that Risk Parity strategy performs well in the turbulent markets and also has the advantages when the market is less volatile because of its lower standard deviation. To have a deep analysis of the strategy performance, I will look at the annual performance of the sample period and relate the findings to the correlation between asset classes and asset weightings.

Table 3 is a summary of average monthly return and Sharpe ratio for three strategies for every trading year of the sample period. Negative Sharpe Ratio is not analyzed in this study because it makes little sense when the excess return is lower than the risk-free rate. The results from Table 3 are greatly consistent with Table 2 but have some exceptions. In the year 2009, Unlevered Risk Parity performs worst. In the year 2013, it has the largest monthly loss and in the year 2014, Naïve Risk Parity portfolio has the highest ratios while Unlevered Risk Parity is secondary to it. The monthly return and Sharpe ratio of Risk Parity are really high in 2010 and 2011, especially in the year of 2010 when its Sharpe ratio is 1.916. It is also worth of attention that in the most recent years, such as 2015 and 2016, the difference between these three strategies is comparably small, which means Risk Parity seems less attractive.

Table 3: Summary of Average Monthly Return and Annualized Sharpe Ratio for each year of the sample period*

	2008		2009		2010		2011		2012		2013		2014		2015		2016	
	AMR	SR	AMR	SR	AMR	SR	AMR	SR	AMR	SR	AMR	SR	AMR	SR	AMR	SR	AMR	SR
Equal Weighted	-4.21%	-1.362	1.74%	1.025	0.38%	0.310	0.16%	0.116	0.41%	0.452	-0.24%	-0.368	0.28%	0.357	-0.79%	-1.143	0.75%	1.325
Naïve Risk Parity	-3.23%	-1.373	1.30%	1.068	0.61%	0.669	0.19%	0.193	0.37%	0.515	-0.20%	-0.360	0.46%	0.709	-0.67%	-1.287	0.68%	1.616
Unlevered Risk Parity	-1.34%	-0.889	0.61%	0.678	0.84%	1.916	0.60%	1.061	0.30%	0.711	-0.33%	-0.658	0.40%	0.635	-0.59%	-1.664	0.69%	1.836

Note: AMR and SR in table 3 are abbreviations of average monthly return and annualized Sharpe ratio.

The performance of Risk Parity strategy is largely contributed from its rebalancing asset weights, which in turn are influenced by the asset correlations. Figure 4 is the three-month rolling average correlation across nine asset classes starting from September 2008 to October 2016.

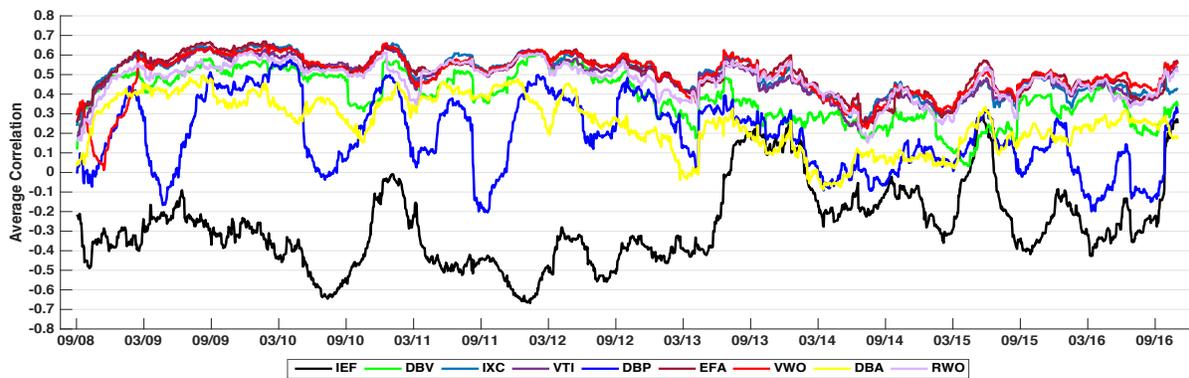


Figure 4: 3-Month rolling average correlation across all asset classes

It can be seen from the graph that the black line of IEF, which represents the asset class of Fixed Income, is the most uncorrelated asset class as it usually has a negative average correlation with other constituents. The line of DBP, which is from precious metals, has the same trend as IEF because gold is always regarded as the safe-heaven assets like treasury bonds. Asset classes under Equities always have higher and similar correlations, which are shown as the lines of IXC (Energy), VTI (US Equity), EFA (Emerging Markets Equity), VWO (Developed Markets Equity) and RWO (Global Real Estate) have almost the same correlations with other asset classes in the sample period. Based on the theory of Risk Parity, any asset class with lower correlation will have higher weights. From Figure 5, the gross weight allocation for Unlevered Risk Parity, IEF accounts for the major weight of the portfolio. Compare Figure 4 with Figure 5, it is obvious

that the weight of IEF changes in the opposite direction with its correlation with other assets. When the correlation of IEF surges at the beginning of 2011 and during 2013 and 2015, its weighting drops accordingly.

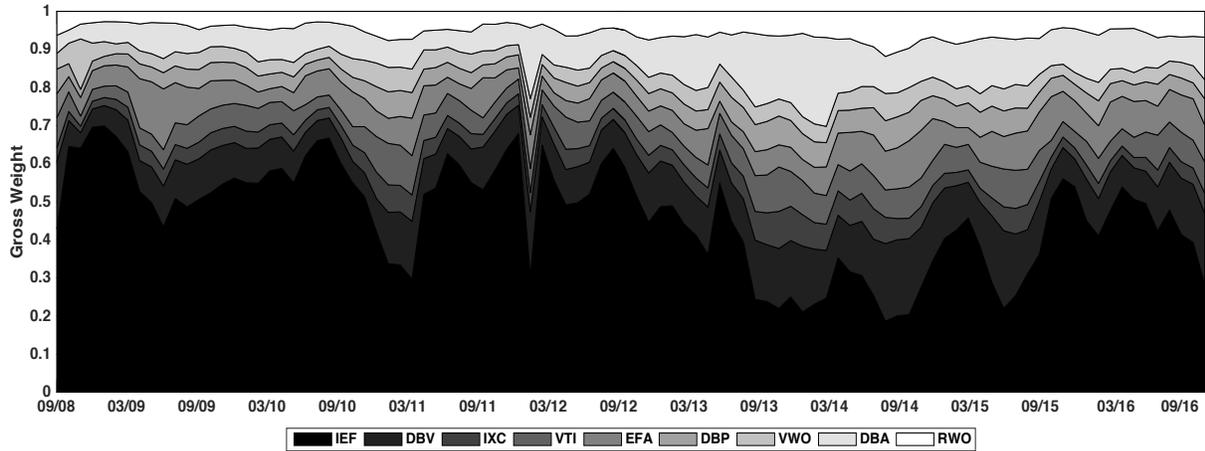


Figure 5: Gross weight allocation for the unlevered Risk Parity portfolio

The underperformance of Risk Parity strategy in the year 2009 is primarily driven by the fact that during the post-crisis period, as the prices of Equity ETFs have dropped largely, they have more upside potentials. Because IEF accounts for nearly 50% of the portfolio, lower weights in equity ETFs make RP Strategy less profitable but stable. Same reasons exist at the end of the year 2014 when IEF weight increases from a relatively low level. The outperformance of Risk Parity portfolio in 2011 is shown in Figure 2, when the Equity market is not good, overweights in Bond ETFs make the overall portfolio less exposure to the volatility and stay stable while other two portfolios perform poorly. It can be seen from Figure 4 that in the most recent period, the average correlations have an overall upward trend, especially at the end of the sample period when all asset correlations are rising and concentrated. As mentioned before in Naïve Risk Parity methodology, when the correlations between asset classes are equal, Naïve Risk Parity can realize true risk diversification. And that's the reason why all three strategies have almost the same returns. Besides, the volatility is quite low nowadays as the market reacts quickly to all circumstances without severe and lasting impacts. Risk Parity strategy is, therefore, less favorable when volatilities are lower across all asset classes.

4.2 Performance Evaluation of the second sample period

In the last part, I have compared the Unlevered RP strategy with EW and Naïve RP strategies in an 8-year sample period. The emphasis of this part is to see how leverage works under the Risk Parity weighting scheme and the influences of two different leverage methods.

Figure 6 presents the cumulative returns for these five portfolios starting from February 2010 to October 2016 and Table 4 shows the annualized return, standard deviation and Sharpe ratio and maximum drawdown during the who sample period.



Figure 6: Cumulative returns (non-annualized) for five strategies from Feb 2010 to Oct 2016

Table 4: Statistical comparison summary for five strategies (Feb-2010 to Oct-2016)

	Annualized Return	Annualized Std Dev	Sharpe Ratio*	Maximum Drawdown
Equal-Weighted	2.827%	11.903%	0.2291	21.508%
Naïve Risk Parity	3.142%	8.978%	0.3388	16.532%
Unlevered Risk Parity	3.022%	5.767%	0.5076	14.457%
1.5X Levered Risk Parity	3.313%	8.119%	0.3957	18.255%
1.2X Levered Risk Parity	2.848%	7.062%	0.3891	17.634%

Note: Risk-free rate (0.10%) used in Sharpe ratio is the average of annual 3-month Treasury Bill rates from Feb 2010 to Oct 2016

Since the sample period in this case is shorter than the last one, and it has fewer influences from the financial crisis. The market performances of Unlevered RP, EW and Naïve RP portfolios are slightly different as the results above. In Figure 6, from the period of Feb 2010 to the end of the year 2011, 1.5X levered Risk Parity, EW and Naïve RP portfolios have a comparably similar trend as they all have larger exposure to Equity ETFs that perform well in this period. From the beginning of the year 2012, because 1.5X levered Risk Parity is constructed on a risk-allocation basis, it has properties of risk diversification and has a much closer trend with Unlevered Risk parity and 1.2X risk parity portfolios as well as smaller drawdowns when comparing to EW and Naïve RP approaches. The use of leverage does make sense in this case as the annualized return of 1.5X levered Risk Parity portfolio is the highest among these five trading strategies. However, another 1.2X levered Risk Parity portfolio, which is constructed using the leveraged ETF, has comparably lower annualized return. And it almost has the same but even worse performance as unlevered one. The reason may be the way the portfolio is constructed, which still overweights Bond ETFs at most time and thus has less return from Equity ETFs. And because of the using of leveraged ETF, the risk exposure of Fixed Income is larger, thus the 1.2X levered RP portfolio performs poorly when Bond ETFs have negative returns.

Leverage is always considered to be risky as the portfolio changes dramatically, however, in this case, the annualized volatilities for 1.5X levered Risk Parity portfolio is only 8.119%, lower than the EW and Naïve RP portfolios. Although the downside risk of 1.5X Levered Risk Parity portfolios is relatively high as the maximum drawdown is 18.255%, it's acceptable because it is just 4% higher than the lowest number. Because of its very low annualized volatility, which is only 5.767%, Unlevered Risk Parity has the highest Sharpe ratio. 1.5X levered Risk Parity is secondary to it but with a lower Sharpe ratio, 0.3957.

5: Conclusion

Risk Parity, a more sophisticated asset allocation scheme, has attracted significant attention in recent years, especially in the financial crisis periods when the correlation between different asset class increases. Traditional asset allocation techniques focus on asset-based diversification and add lower or negative correlated assets to the portfolio. While Risk Parity strategy emphasizes on risk-based diversification that makes sure each constituent has equal risk contribution to the overall portfolio. And it needs a large effort to solve the optimization problem of portfolio weights.

I have compared the performance of five different strategies in two sample periods. My finding that Risk Parity strategies have highest Sharpe ratios in both sample periods is consistent with previous studies. But evidence from sample period September 2008 to October 2016 shows that Unlevered Risk Parity has higher cumulative returns, which is different from most studies. It is because the sample period in this paper starts from the financial crisis when Risk Parity performs well and thus influences later performance. The inconsistency proves that the performance of strategies is very sensitive to the selected sample period, which satisfies previous studies. The evidence from the second sample period shows that leverage with borrowing money enhances strategy performance as the annualized returns are higher and the portfolio volatilities are acceptable since the Sharpe ratio is comparably high.

Correlation and volatilities are two key factors in Risk Parity strategy. In this study, I have found that the correlations between sample asset classes tend to be concentrating and positively related. As the markets become less volatile and react mutely to turmoil, Risk Parity seems to be less favorable. Additionally, the yields of Bond ETFs will be much lower with the passage of 30-year bull bond markets. With these concerns, further work can be done to explore better measurements of risk and correlation, rebalancing frequency and apply the principle of Risk Parity to more trading strategies.

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