Global Asset Allocation Based on Principal Component Risk Parity Model

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Abstract. Contemporarily, as the economy enters the new normal, Chinese real estate prices that rose almost unilaterally in the past will be difficult to appear again. With just break, the high yield of wealth management products will no longer be the scene. Therefore, the importance of risk diversification among different assets, i.e., the allocation decision of major assets, becomes more and more prominent. This paper mainly investigates the application of principal component risk parity model in asset allocation. Specifically, the article focuses on the result of the experiment and the importance of this model. In the experiment, the principal component risk parity model is compared with the traditional risk parity model. At the same time, the principal component parity risk model is further analyzed and compared with other models from the related formulae derivation. Finally, the corresponding conclusions are drawn, and the advantages and necessity of rational usage of risk parity model in asset allocation are put forward. Overall, these results shed light on guiding further exploration of finding efficient models to help with asset allocation.

Keywords: Principal component risk parity model; Asset allocation; Traditional risk parity model.

1. Introduction

The foundation of asset allocation is the idea that returns from various asset classes are not completely correlated, and therefore spreading portfolios among them will help to maximize risk-adjusted returns. It wasn't until 1986 that Gary P. Brinson, CFA, Randolph Hood, and Gilbert L. Beebower (together known as BHB) attempted to elucidate how asset allocation strategy affected pension plan returns [1].

Principal component analysis (PCA) was invented by Carl Pearson in 1901 to analyze data and build mathematical models [2]. It is similar in principle to principal axis theorem. It was then independently developed and named by Harold Hotelling around 1930. It is also called discrete K-transformation in signal processing, depending on the application domain. As a basic mathematical analysis method, PCA has a wide range of practical applications, such as demography, quantitative geography, molecular dynamics simulation, mathematical modeling, mathematical analysis and other disciplines, which is a commonly used multivariate analysis method.

The asset pool studied in this paper includes the stock market and domestic bonds, and explores the realization of asset allocation with high diversification and low risk portfolio, and obtain stable wealth appreciation. However, the risk parity model is often used in the current asset allocation practice. The traditional risk parity model will assign investment weight to all assets, so as to ignore the correlation between assets. That risk principal component par model can carry on the linear transformation of the original assets form orthogonal combination of principal component. Subsequently, one can determine the composition of the main combination weights of investment by traditional risk parity model, as well as the final transformation for the original assets investment weights. In this case, it is available to better solve the traditional model to handle the related high risk parity, the weakness of the asset allocation problem.

This paper mainly focuses on the specific application of principal component risk parity model in the field of global asset allocation, and compares the traditional risk parity model based on risk factors with the principal component risk parity model. On this basis, it is able to obtain the advantages of the principal component risk parity model compared with other models. In this paper, the principal component analysis method is used to transform the asset portfolio into the principal component factor combination, and the solving method of the risk parity model based on the principal component risk factor is constructed on the basis of the traditional solving method of the risk parity model, and the causes of such advantages are speculated. The rest part of the paper is organized as follows. The Sec. 2 will introduce the preparation of data and the method to get relevant results. The Sec. 3 will give the result and make the final decision. The Sec. 4 will clarify the drawbacks for this study as well as propose the future outlooks for further investigation. Eventually, a brief summary will be given in Sec. 5.

2. Data & Method

2.1 Data Preparation

The asset pool of asset allocation in this paper includes: Shanghai and Shenzhen 300, Sany Heavy Industry, Nikkei 225, China's oil, Citic Securities, Shanghai 5-year Government Bond Index, Shanghai Futures 30 Index, Hang Seng China Enterprise Index, NASDAQ Global Index, and China Beacon & Poor's 300, which covers 10 types of assets, including major global stock markets and domestic bonds. The closing price data of the above indexes from January 2015 to September 2022 are selected. For the convenience of data processing, the closing price data of the above assets are saved as' Global Asset Index Quotation Series.XLSX '. This study loads the global asset index market sequence, draws the net value of all kinds of global asset index in Fig. 1.

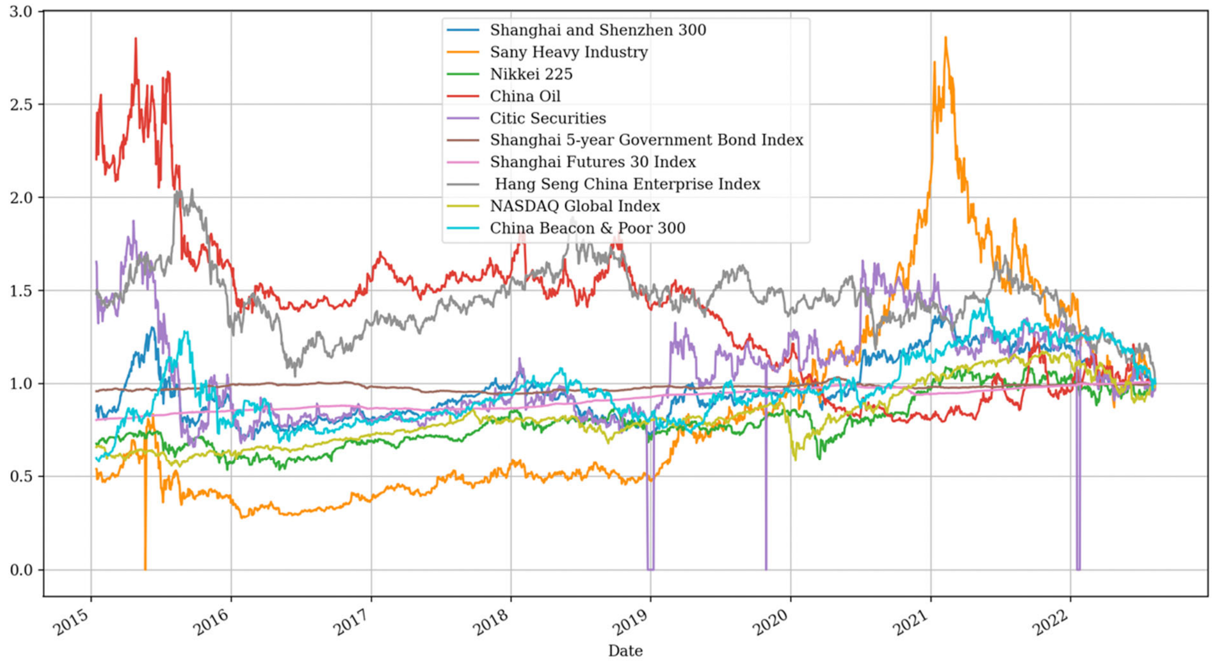

Fig. 1 Net Value of All Kinds of Global Asset Index

2.2 Principal Component Risk Parity Model

The era of asset allocation has quietly begun in the current global environment of negative interest rates, high volatility, and low returns. The traditional single market cannot accommodate the complicated investment environment of today. To achieve the anticipated return, investors must have a broad perspective on asset allocation and search for assets with a higher income ratio in comparison. In fact, different investors have different opinions on the logic of asset allocation and the categories of preferred assets. The analysis shows that the asset allocation model is mainly composed of three factors, namely, the return of assets, the risk of assets and investors' views. The cross of the three factors jointly forms the whole asset allocation model system. Asset allocation, however, aims for a low-risk portfolio and more importantly, sustained wealth growth under low-risk circumstances. For the needs of significant asset allocation, traditional portfolio models that aim for high risk and high return are unsuitable. In the meantime, numerous studies have demonstrated that models with modest parameter estimation and pure models can frequently produce better and more consistent returns. From the original equal-weight model to the mean-variance model, as well as the introduction of behavioral finance to the asset allocation model, people have witnessed the development of modern portfolio theory. However, while continuing to study, researchers will reflect on past research results and find that the more complex the model is, the better it is. The more complex the model is, the more parameters it needs, and the worse the stability of out-of-sample prediction will be. At the same time, the momentum impact of asset returns is limited, which means that good asset return performance in the past may not guarantee good performance in the future. The momentum effect of asset volatility is considerable, but asset volatility has historically been low and there is little chance that it will be high in the future [3-5].

The constant weight technique, which allocates various assets with a constant weight, is the most fundamental in the development of a portfolio. This kind of approach offers attributes including simple operation and minimal operation cost, which does not require assuming the future state of assets. Equal Weight is the most typical of them all (EW). There are also 60-40 traditional asset allocation strategies for stocks and bonds. According to DeMiguel et al., the fundamental 1/N model can produce a sharper ratio out of sample than the conventional mean-variance model. However, because of its great subjectivity and inability to adapt to changes in market conditions, this type of technique fails to accomplish the goal of diversified investment and causes the portfolio to be significantly impacted by some assets.

A new asset allocation method is called risk parity, often known as equal risk contribution (RP). When weighing different assets in a portfolio, RP demands that the portfolio's overall risk be evenly distributed among all assets, i.e., that the risk exposure to each asset class be the same. The portfolio with a more diversified risk can be obtained in order to remove the unbalanced contribution of various assets to portfolio risk. Researchers suggest equal-risk pairings to make sure that each asset contributes the same amount of risk [6].

$$RC_i = RC_i \; for \; all \; i \neq j \leftrightarrow w_i \frac{(\sum w)_i}{\sqrt{w' \sum w}} = w_j \frac{(\sum w)_j}{\sqrt{w' \sum w}} \; for \; all \; i \neq j \tag{1}$$

$$\leftrightarrow \sum_{i=1}^{n} \sum_{j=1}^{n} (RC_i - RC_j)^2 = 0 \leftrightarrow \sum_{i=1}^{n} \sum_{j=1}^{n} w_i (\sum w)_i - w_j (\sum w)_j)^2 = 0 \tag{2}$$

The aforementioned equation can be translated into the following optimization model to determine the ideal weight:

$$\min_{w} \sum_{i=1}^{n} \sum_{j=1}^{n} [w_i (\sum w)_i - w_j (\sum w)_j]^2 \tag{3}$$

$$\text{s.t.} \begin{cases} \sum_{i=1}^{n} w_i = 1 \\ 0 \leq w_i \leq 1, i = 1,2,\dots,n \end{cases} \tag{4}$$

The risk parity model has strong universality and is applicable to asset allocation, single asset classes, factor combinations, and models. The risk parity model seeks to balance the risk of various asset classes and optimizes the investment weight from a risk perspective. However, the optimization of the ultimate investment weight may be impacted by the inherent correlation between assets. The risk parity model will assign investment weight to the asset as long as it fluctuates, directly affecting the quality of asset allocation as the quality of asset selection.

According to the current risk parity model, it is preferable to identify the uncorrelated risk factors behind the factors in order to solve the asset allocation problem of correlated assets and ensure that the risk factors balance the risk. Therefore, this paper tries to form uncorrelated investment portfolios by linear combination of the original assets, and carries out asset allocation of risk parity model for the uncorrelated portfolios, finally determining the investment weight of the original assets [7].

In 1901, Pearson first suggested principal component analysis (PCA), which was then investigated by Wold and Hotelling to produce the present iteration. PCA is a type of multi-asset based on dimension reduction through mathematical transformation into a few principal components (i.e., comprehensive variables) of multivariate statistical analysis method. The principal component can reflect the majority of the original asset information, making it more realistic. It is typically characterized by a linear combination of the original assets, making the information contained in these principal components overlap each other. The main concept is to isolate all unrelated assets for risk parity model analysis, rotate the underlying assets in the portfolio using principal component analysis, and then determine the investment weight of the original assets in reverse.

The covariance matrix of the assets can be calculated using the rate of return of the N assets, assuming that there exist N assets in the portfolio and that the rate of returns of the assets is R, given the portfolio weight W and the total return of the portfolio. The covariance matrix can be divided into N orthogonal eigenvectors because of its symmetry. The eigenvectors, sometimes referred to as primary component factors, can create N orthogonal portfolios. The findings can be achieved by applying the risk parity model to the component factors and the concept of risk contribution. The weights of the principal component factors can be made up of linear combinations of the original weights.

3. Results & Discussion

Primarily, this study calculates the correlation matrix of each asset and presents it as a heat map as illustrated in Fig. 2. According to the results, China Oils highly correlated with Citic Securities. It can be seen that they can be respectively regarded as a group of assets. The risk parity model and principal component risk parity model are used to backtest the aforementioned asset portfolio. Rebalance asset risk at the end of each quarter. The return on assets covariance matrix is estimated based on historical trading days. The asset weight (weight) and risk contribution (risk) of each positioning node are saved in the calculation process [8, 9].

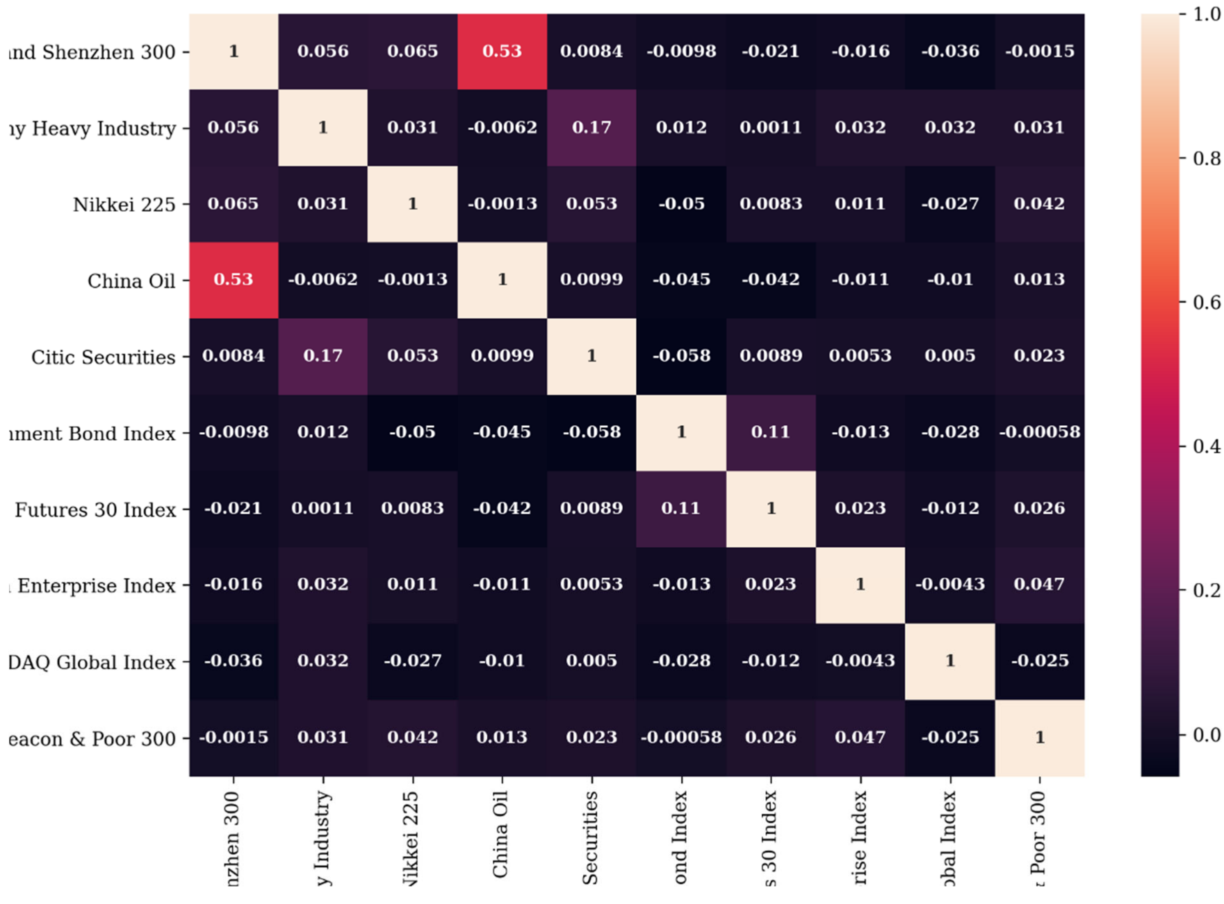

Fig. 2 Heatmap of the correlation coefficients between different underlying assets.

According to the historical asset weight and daily return rate, the care respectively exhibited in Fig. 3. It can be seen that the net value curve fluctuation of PCRP model is significantly lower than that of RP model, and the yield is also better than that of RP model. The calculated yield is given in

Table. 1. Seen from the results, PCRP model obtained a higher yield rate than that of RP model. Therefore, it can be concluded that the principal component risk parity model has obvious advantages over the traditional risk parity model in terms of returns.

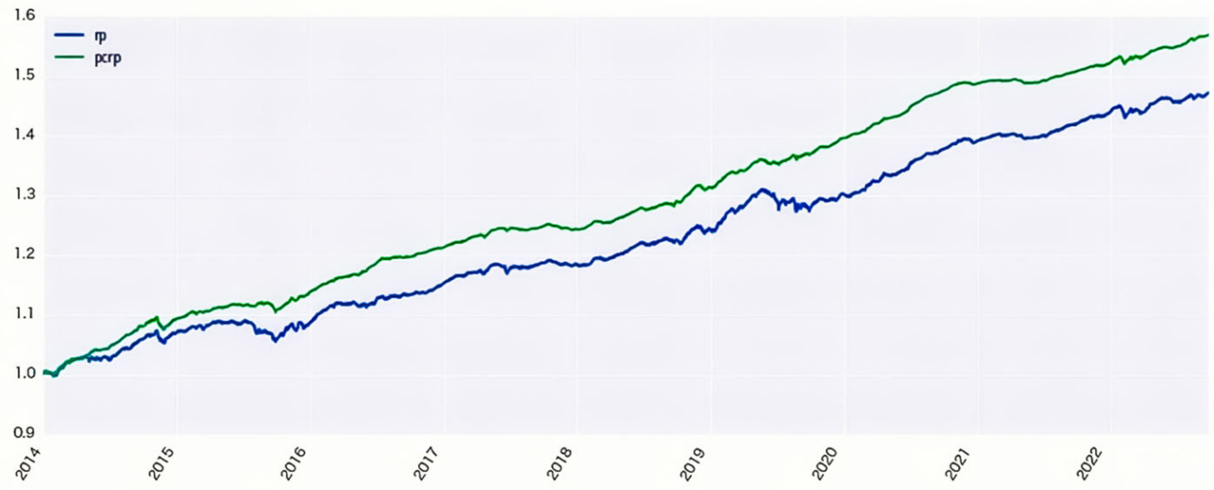

Fig. 3 Net Value Curves of Risk Parity (RP) Model and Principal Component Risk Parity (PCRP) Model

Table 1. Yield Rate

Years	RP	PCRP
2014	1.43%	1.43%
2015	7.90%	9.84%
2016	9.56%	14.53%
2017	14.98%	22.47%
2018	18.79%	25.07%
2019	24.63%	32.17%
2020	30.03%	40.00%
2021	39.54%	49.17%
2022	44.58%	52.79%

4. Limitations & Prospects

This study mainly analyzes a global asset allocation strategy based on principal component risk parity model and proves its advantages compared with traditional models. However, there are still many improvements in the strategy construction, e.g., the fixed time point of position adjustment rather than dynamic, and the analysis is not combined with the characteristics of different markets. In the future, more underlying assets should be included with longer investigation period. Besides, other prediction tools (e.g., machine learning) can be applied to forecast the volatility of the underlying assets in order to achieve better performance [10].

5. Conclusion

In summary, this paper investigates Global Asset Allocation Based on Principal Component Risk Parity ModelRisk parity model is the nature of hope to completely irrelevant or low correlation between assets to risk equilibrium configuration, but the reality of assets have high correlation, principal component analysis (PCA) based on different assets, in the orthogonal space to achieve the goal of risk such as contribution, solved the problem of the high correlation between assets repeat configuration. The function of filtering assets. According to empirical results, the principal component risk parity portfolio has higher returns and smaller fluctuations than the traditional risk parity portfolio. This study mainly studies a global asset allocation strategy based on principal component risk parity model and proves its advantages compared with traditional models. However, there are still many improvements in the strategy construction, such as the fixed time point of position adjustment rather than dynamic. In addition, the analysis is not combined with the characteristics of different markets. In the future, the principal component risk parity model will be more and more applied to various types of asset allocation and play a positive role. Overall, these results offer a guideline for more and more risk parity models based on different optimization models.

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