Asset Allocation and the Optimization Portfolio Choice for the Retired Firefighter

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Abstract. Asset allocation and portfolio management have become quite important as the fast development of the global finance and the tremendous improvement of people's life. This paper aims at helping the retired firefighter employ his pension to allocate the assets and find the optimization of the portfolio. He has 2 different choices and the paper also need to make a comparison of them based on the quantitative analysis. In this paper, the Fama-French 3 Factor model is used to run the regression of the historical data between different assets and the influential factors to illustrate the features of each asset. Under the construction of the mean-variance analysis, it helps form the optimization of the portfolio, meanwhile, with the help of solver, the maximized Sharpe ratio is calculated. Then, the biggest Sharpe ratio of the 2 different choices and the corresponding weights of the assets are shown. The final results show that taking the pension benefit and investing his nest-egg to supplement the pension benefit is a better choice than gaining all the money at one time and investing it to the market because of the lower standard deviation. The results can be applied to the portfolio management of the retirees which are of great practical significance.

Keywords: portfolio management · asset allocation · Fama-French Three Factor model · personal tailor

1 Introduction

Christine pointed out: As individuals lay much emphasis on ensuring their own financial future, portfolio or fund management is becoming significantly necessary and crucial [1]. In addition, Gosse suggested that differences in risk preference indicate different optimal asset allocations. [2] That means as the financial advisors, it is necessary to design different investment portfolios of different characteristics for different clients. Considering that most elderly are the risk aversions, they are not willing to take big risks for big returns, so the advisors are ought to offer them a diversified portfolio choice which includes assets of different fields because as Hosseini & Hamidi put it, diversification will help to minimize the risk. [3] Therefore, asset pricing and portfolio management is quite significant for the potential investors especially the elderly who have enough money which is to be allocated.

F. Balli et al. (Eds.): ESFCT 2022, AEBMR 226, pp. 1513–1520, 2022.
https://doi.org/10.2991/978-94-6463-052-7_167

There are numerous investigations and tremendous materials regarding portfolio management. The methodology of asset allocation and portfolio optimization the paper will use is relatively full-fledged, for example, Viviane used the investment-strategy model to analyze the environmental hazard of the global reserves [4]; Wolfgang et al. employed optimal asset allocation strategies for equity portfolio around the whole world [5]; Yuyeong et al. researched network for index-tracking portfolio optimization [6]; Zhi and Wang studied the portfolio optimization for inventory financing [7], Ali, Nader and Gholamreza investigated the importance of asset management in the field of building facilities [8]; As about the real assets, Jarosław and Janusz discussed the tactics based on mathematic and quantized way which can be really useful [9]. However, a mass of studies of portfolio optimization emphasize mainly on enterprise level, financial literature and different industries but there are still limited studies in the portfolio management and the specific investment strategies for individualities especially for the retirees. But helping those allocate their portfolio investment by using their pension funds is crucial because just as Gosse et al. put it, pension funds are some of the largest investors in the world, with considerable impact on stock markets [10]. Meanwhile, the reasonable choices of pension funds also help the retirees improve their living qualities. However, few investigations especially pay attention on the elderly.

Fama-French proposed the three-factor model as an improvement and amendment of the CAPM model. The three-factor model is aimed at explaining the different risk premium factors which will influence the average returns in the stock market. This paper combines the Fama-French three factor model and the modern portfolio theory. And the empirical process is summarized as follows.

First, the paper calculates excess return just using the respective return minus the risk-free rate. (The market return rate, SMB, HML and risk-free rate have already been downloaded from the website). Second, run the correlation of the stocks which have been chosen in order to see whether one asset may have a high correlation with other ones. If this situation happens, it is necessary to drop the highly correlated ones. Luckily, the assets which have been chosen to have a low correlation with each other, so they are use as portfolio choice, then, this paper runs a covariance of them to prepare for the later use. Fourth, run regression on our 2 stocks and 3 mutual funds. The results show the different beta and alpha of different choices. The results are reasonable to be good choices. Fifth, it is time to allocate the different weights of portfolios. In order to maximize return, it is necessary to pay attention on Sharpe ratio. The Shape ratio is equaled to the expected return minus the expected risk free rate divided by standard deviation. With the help of solver to find the allocation of different assets to maximize the Sharpe ratio. Sixth, think of the other option. One choice is to take the lump-sum payout and invest his nest-egg and the lump-sum, the other one is to take the pension benefit and invest his nest-egg to supplement the pension benefit. Finally get to know the Sharpe ratio and make a comparison between this option and the former one.

The rest of this paper is summarized as follow. Section 2 depicts the data. Section 3 refers to the methods. Section 4 presents the results and Sect. 5 is the conclusion.

2 Data

The data is searched and downloaded from Yahoofinance (https://finance.yahoo.com/). In order to help the firefighters to manage his asset and reduce the risk, the paper choose 2 single stocks and 3 mutual funds which involve different fields. As the single stock is riskier compared with mutual funds but it is still necessary to diversify the portfolio. The selected assets are DIS, USS, PCAFX, ZEOIX and ADAMS, respectively. And the full sample period is from April 1, 2017, to April 1, 2022. However, the further study only needs the data from May 1,2017 to January 1,2022, so deleting some data unnecessary is necessary. Then, the paper makes a basic analysis of the raw data (Table 1).

From the above table, the paper found that US steel (USS) had the highest mean return while the mutual fund ZEOIX had the highest return. Furthermore, ZEOIX had the lowest variance, and the USS had the highest variance which means it is not so stable. In addition, USS had the biggest maximum return and the smallest minimum return; ZEOIX had the smallest maximum return, but the highest minimum return compared with other ones.

3 Methods

3.1 Correlation Coefficient

When the data has been initially processed, it is necessary to run the correlation of the assets in order to see whether one asset may have a high correlation with other ones. If this situation happens, drop the highly correlated ones. The correlation coefficient is:

$$\rho_{X,Y} = \frac{Cov(X,Y)}{\sigma_x \sigma_Y} = \frac{E[(X-\mu_X)(Y-\mu_Y)]}{\sigma_X \sigma_Y} \tag{1}$$

3.2 Fama-French Three-Factor Model

The formula has been chosen is the Fama-French three-factor model. Comparing with the classical CAPM model, it has more benefits. Because the CAPM model only takes the systemic risk into consideration, it simply regards the returns of portfolio are only related to systemic risk, so it leads to misvaluation and too much random disturbance error. For in real world, more factors are required to take into consideration, for example, HML (returns from high B/M stocks less returns from low B/M stocks), SMB (returns from high market cap less returns from low market cap stocks). They are so important. Meanwhile, it is more suitable for numerous stocks and portfolios comparing with other 5 or 6 factor models. So far, Tzu-Lun Huang did a research on Chinese stock market in recent year and found the 5 factor model has some disadvantages and the 3-factor model is confirmed to be a better choice[11]; Horváth and Wang found that the FF3F-model explained the excess returns of the stocks during the COVID-19 pandemic[12]; Dev R.Mishraa and Thomas J.O'Brien proved that when comes to compare the connotative cost of different equity, the FF3F model is superior to CAPM model. [13]. The formula of the model can be written below:

$$R_{it} - R_f = \alpha_{it} + \beta_1\left(R_{Mt} - R_{ft}\right) + \beta_2 SMB_t + \beta_3 HML_t + \epsilon_{it} \tag{2}$$

The meanings of symbols in the above equation are shown below in Table 2.

Table 1. Descriptive statistics of the assets

	DIS	USS	PCAFX	ZEOIX	ADAMS
Mean	0.007	0.016	0.009	0.002	0.014
Variance	0.007	0.031	0.002	0.0003	0.003
Max	0.23	0.659	0.116	0.0393	0.180
Min	–0.180	–0.315	–0.144	0.110	−0.124

Table 2. Meanings of symbols

Symbol	Meaning
R_{it}	Total return of the asset i at time t
R_f	Risk free rate of return at time t
R_{Mt}	Total market portfolio return at time t
$R_{it} - R_f$	Expected excess return
$R_{Mt} - R_{ft}$	Excess return on the market portfolio
$\beta_{1,2,3}$	Factor coefficients
SMB_t	Returns from high market cap less returns from low market cap stocks.
HML_t	Returns from high B/M stocks less returns from low B/M stocks

3.3 Mean-Variance Analysis

This methodology is included in the modern investment theory, which is widely used among quantitative finance. It has two main functions: when the level of risk is certain, it helps to find the maximum return; when the return is given, it is conducive to obtain the minimum risk.

$$E(R_P) = \sum_{i=1}^{n} \omega_i E(R_i) \tag{3}$$

$E(R_p)$ represents the expected return of the whole portfolio, ω_i denotes the different weight of the chosen stock or mutual fund, where $\sum_{i=1}^{n} \omega_i$ equals to 1. $E(R_i)$ denotes the expected return of each asset.

$$Var(assets\ return)$$

$$= \sum_{1,2} weight_1 \cdot weight_2 \cdot Cov[assetbenefit_1, assetbenefit_2] \tag{4}$$

In this methodology, the variance is also needed to take into consideration. Var is short for variance, under this circumstance is the variance of the whole investment portfolio, Cov is short for covariance between the rewards of asset i and asset j.

Table 3. The summarizing of the regression results

	β_1	β_2	β_3	α_{it}
DIS	1.163 (0.181)	0.043 (0.311)	0.124 (0.202)	−0.008 (0.009)
USS	1.657*** (0.446)	0.598 (0.767)	0.885* (0.497)	−0.002 (0.021)
PCAFX	0.730 (0.089)	−0.163 (0.153)	0.357*** (0.010)	0.0007 (0.004)
ZEOIX	0.183 (0.035)	0.099* (0.060)	0.114*** (0.040)	−0.00006 (0.002)
ADAMS	0.912 (0.113)	−0.188 (0.195)	0.076 (0.126)	0.003 (0.005)

Table 4. The allocation of the assets including the pension for the maximum Sharpe ratio

	DIS	USS	PCAFX	ZEOIX	ADAMS	PENSION
Average Expected Return	0.009	0.016	0.007	0.003	0.007	0.006
Weight	0.016	0.027	0.017	0.302	-0.071	0.71
Expected Return	0.005					
Variance	5.63E-05					
Stand Deviation	0.008					
Sharpe Ratio	0.609					

This method helps allocate the different weights of portfolios. In order to maximize the returns, it is necessary to pay attention to Sharpe ratio. Which can be written as:

$$SharpeRatio = \frac{E(R_P) - R_f}{\sigma_P} \tag{5}$$

It is equaled to the expected return of the whole portfolio minus the expected R_f divided by standard deviation of the portfolio. So $E(R_P)$ is the reward of the portfolio, R_f represents the risk free rate, and σ_P means the standard deviation of the portfolio.

4 Results

First, in order to ensure the authenticity and the accuracy of the data, the regression results of different assets are needed to be shown below. In order to be more concise and readable, the paper shows the summarizing of the results, which omit the information that is not useful for future research and maintain the information which is important in a clear way.

Table 5. The allocation of different assets for the maximum Sharpe ratio

	DIS	USS	PCAFX	ZEOIX	ADAMS
Average Expected Return	0.009	0.016	0.007	0.003	0.007
weight	0.040	0.038	0.265	0.523	0.135
Expected Return	0.005				
Variance	0.0008				
Stand Deviation	0.029				
Sharpe Ratio	0.149				

From Table 3, it is clear that despite ZEOIX, all the assets have the similar β_1, approximately around 1, which means the asset risk is the same as the market risk, though ZEOIX has a low β_1, it shows that the risk of this asset is less risky than the market average. So, it does not have a bad influence on the choice and the final result.

Then it is time to allocate the different weights of portfolio. In order to maximize return, pay attention on our Sharpe ratio. Before that, it is necessary to calculate the $E(R_{Mt} - R_{ft})$, $E(SMB_t)$, $E(HML_t)$ and $E(R_f)$. Then, calculate the respective expected returns of each stock or mutual fund. The expected return of each asset equals to the expected risk free rate of 5 years plus the regression results of each factor multiply by their corresponding expected values. The preparation for the expected return of portfolios has been made as a whole. It just equals to the expected return of each asset times its weight. After that, calculate the variance and the standard deviation using the covariance. The shape ratio is equaled to the expected return minus the expected rf divided by standard deviation. Then it is time to use the function of solver to help find the allocation of different assets to maximize the Sharpe ratio.

Finally, take the other option into consideration. Under the second circumstance, the pension should be regarded as a kind of long-term bond, so calculate its excess expected return and add its weight to the portfolios. It is well-noted that it occupies a fixed rate of 71%, that means that he is constrained to have a large percentage of his wealth tied up with the state pension fund. Then also with the help of the solver, the results show the Sharpe ratio and make a comparison between this option and the former one. From the table, it is easy to see that in order to maximize the Sharpe ratio, the weight of ZEOIX is the highest, about 52.3%, and USS only occupies 3.8% (Tables 4 and 5).

The two tables above show the different Sharpe ratio of two different choices of the firefighter. The first choice is that he takes all the money in one time, the second choice is that he takes the pension for every month. The results show that the Sharpe ratio of the first choice is 0.149 the standard deviation is 0.029101, the second Sharpe ratio is 0.609 and the standard deviation is 0.007503. In this case, due to the fixed weight of pension, ZEOIX still has the highest weight compared to others, about 30.3%, but DIS only occupies 1.6%.

5 Conclusion

Nowadays, though a great number of papers have already paid much attention on portfolio management, most of them are concentrated on macroeconomics. In microeconomics fields, most of them are centered in the asset optimization of different industries and corporations, just like the optimization for network, for index-tracking portfolio, for inventory financing portfolio, for architecture and building facilities portfolio and so on. Many researchers nearly neglect the portfolio management for personal tailor. In this paper, using the classical model of FF3F model and based on the time sequence, it helps the retiree design and calculate the better portfolio choice to gain the benefits. The paper employs the important factors and the model to run a regression to get the different β, then with the help of solver function and the basis of the mean-variance analysis, further, to get the maximum Sharpe Ratio. Comparing the results of the two scenarios, the second option is better because do not need to calculate the results with the exact numbers, the Sharpe Ratio of the first choice is 0.147 but the second one is 0.435, so obviously, the second one is better, it has a much higher Sharpe ratio. So, the paper recommends the second choice, that means he should accept the defined benefit. Meanwhile, there are also some deficiencies, the data is limited, and based on the hypothesis, the past performance of the stock market cannot predict future trend precisely; the Fama-French three-factor model may not take all the factors into consideration.

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