Portfolio Design for Chinese Pension Investment

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Abstract. The article mainly discusses the investment of pension savings in China, which is an essential topic due to the aging problem in China. The assets in the portfolio are INTC, TXN, XLP and BRSVX, determined by the asset categories and risk diversification. To simulate the change in pension savings, exchange rate of CNY to USD is applied. The expected returns of the assets are calculated by the FF3F model and portfolio weights are determined by maximizing the Sharpe ratio. The final portfolios are one investing all of the pension savings and one investing only 30% of the pension savings. The maximum Sharpe ratio of the latter portfolio is larger than the former one. They both have higher expected return than most of the assets included in the portfolio and have lower variance than the stocks. The result also shows that single assets instead of funds have greater impact in forming the weight of portfolio. The results in this paper benefit the related investors in financial markets.

Keywords: Portfolio · pension · Sharpe ratio · China

1 Introduction

According to the Seventh China National Census, the elderly over 60 years old accounts for 18.7% of the total population in China. Moreover, everyone has their own pension, and almost everyone will begin to pay for their future pension from long before. Therefore, pension investment has a strong practical significance for everyone. After retirement, pension has made up of a large proportion of income and source of livelihood. Hence reasonable and effective investment in pensions can greatly improve the quality of life of the elderly.

Pension investment is one important source of income of the retired. In order to seek possibility of growth in amount of this fixed asset, pension investment is one of the options. The pension plan in China offers the retired their pension on a monthly basis, so the investors save the money for future investment. As a long-term investment, it will face a greater risk of inflation, so its investment operation must be cautious. Since the investment may be the only saving of the retired, investment plan must pursue high returns under the premise of low risk.

The investment practices of public pension funds have become a topic of major interest to invest a portion of the Social Security Trust Funds in equities [1]. Also, a study analyzes the ability to determine the weight of securities of stocks, bonds, mutual funds and deposits in the implementation of employer pension funds in Indonesia based on

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variables of asset allocation, portfolio turnover, board size, institutional ownership and diversification of the portfolio performance [2]. It can be seen that more attention has been paid to the investment field of pension in the world both developed and developing countries. However, with the impact of COVID-19 on people's lives, people's understanding of investment is bound to change, so people will focus more on the minimization of risk. The research put forward a new pension investment portfolio has been in line with people's ideas in the post epidemic era.

Finding the best portfolio can be viewed as an optimization problem, fuzzy mathematical programming [3], real-coded genetic algorithm and support vector machines [4] all have been used as ideas to solve the optimization problem. Moreover, a model named Black-Litterman overcomes the problems of mean-variance portfolio optimization to enhance asset allocation decisions, which has the reliability of return predictions, smaller estimation errors, and lower turnover [5].

In order to find a possible portfolio for the retired in China when investing their pension money in the post-COVID era, the paper is constructed as three parts. The first part is to choose the appropriate assets for the pension investment, collect the stock data of each one, preprocess the data and calculate the basic statistics. The next part is to use financial models to form different portfolios under different criteria and circumstances. Finally, the outcomes are weighed and analyzed, and sensitivity analysis will be done.

2 Data

Since the stock market in the USA is one of the most developed market, stocks in the American stock market are chosen for investment. The data of the stocks are downloaded from Yahoo Finance (https://yahoo.com/author/yahoo-finance), a large financial website with stock information. The five years' monthly data is downloaded for calculation, for the time period can cover both recent statistics and a whole cycle of bull and bear markets. The adjusted close price is processed by the equation,

$$r_t = \frac{P_t}{P_{t-1}} - 1 \tag{1}$$

where r_t is the return in time t and P_t is the price in time t, to get the returns of each asset.

The asset choice of the portfolio is an essential part of the investment. Research showed that investors can reduce the non-systemic risk of their portfolios by holding securities from different industries [6]. Another research modelled historical data from 1982 to 1997 in the UK and argued that increasing the stock investment ratio of the portfolio when allocating pension funds under the scheme of payment determination can effectively avoid inflation risks [7]. Therefore, only by adopting the strategy of diversified asset composition can the pension investment achieve the maximum diversification of investment risks and strive to maximize investment returns.

The four stocks chosen is Intel Corporation (INTC), Texas Instruments Incorporated (TXN), Consumer Staples Select Sector SPDR Fund (XLP) and Bridgeway Small Cap Value Fund (BRSVX). The first two are companies from the semiconductor field. According to the US semiconductor industry report 2021, issued by Semiconductor

Table 1. Basic statistics of the four assets chosen

	INTC	TXN	XLP	BRSVX
Variance	0.0056	0.0040	0.0015	0.0076
5Y Geometric Average	55.62%	159.47%	62.76%	100.88%
3Y Geometric Average	14.03%	82.81%	52.00%	114.69%

Industry Association, despite the slow growth in sales in 2019, the demand in semiconductor was boosted by the COVID-19 pandemic and the sales have risen. World Semiconductor Trade Statistics reported in June 2021 that the sales volume will continue to grow in 2022. Intel Corporation is one of the best companies designing computer chips and Texas Instruments Incorporated is a worldwide semiconductor company devoted to designing and manufacturing embedded chips for industrial and electronic products. XLP is a famous fund in the section of household consumables holding beverages, personal healthcare and retailing companies. BRSVX is the best-performing mutual fund of 2021. This fund focused on small-cap equities and this strategy has paid off well in the historic economic recovery. The four choices meet the criteria of eliminate risk by having stocks from various industries and company sizes. The variance and geometric average of the assets are shown in Table1.

Table 1 shows that the variances of the four stocks are all below 0.008 with the highest reaching 0.0076 and the lowest only 0.0015. The five years and three years geometric average returns of the four stocks are all positive, meaning they all made profits in the past both in the long and short run. The three years geometric average of INTC, TXN and XLP are all lower than the five years geometric average while BRSVX has higher three years geometric average. The lowest is 14.03%, the three years geometric average returns of INTC and the largest is 159.47%, the five years geometric average of TXN.

Data for Fama French Three Factors Model is downloaded from Data Library in Dartmouth College for the model applied later.

3 Methods

3.1 Correlation

To lower the risk of the portfolio chosen, one way is to check the correlation between the assets composing the portfolio. If the prices of the stocks have high correlation, they may rise and fall simultaneously in the future, thus amplifying the possible risk. While on the other hand, stocks with low correlation may not move together, which can alleviate the loss caused by one stock.

The correlation of two variables can be calculated by

$$\rho = \frac{\mathrm{cov}(X, Y)}{\sqrt{\mathrm{Var}(X)\mathrm{Var}(Y)}} \tag{2}$$

where ρ is the correlation between the two variables X *and* Y.

3.2 Fama-French Three Factor Model

Fama-French Three Factor Model (short as FF3F) is used to calculate the expected returns. The three factors are the market risk, the outperformance of small-cap business to large-cap business and the outperformance of high book-to-market ratio companies to low book-to-market ratio company. FF3F is the modified model of Capital Asset Pricing Model (short as CAPM), and it has advantages over CAPM. When calculating the expected return, the loadings on the last two factors are added, that is, the factors, size and value, are all taken into consideration. Size and value risk premiums may affect the stock prices extensively. Only using the market risk premium is not enough at all since expected returns are affected by multiple risk factors in real life. Therefore, FF3F model has better investment guidance.

The OLS equation of FF3F is

$$\mathrm{r} = \mathrm{r_f} + \beta_1(\mathrm{r_m} - \mathrm{r_f}) + \beta_2(\mathrm{SMB}) + \beta_3(\mathrm{HML}) + \in \tag{3}$$

where r is the expected return, $\mathrm{r_f}$ is the risk-free rate, β is the coefficient of the factor, $(\mathrm{r_m} - \mathrm{r_f})$ is the market risk premium, SMB is the excess return of small-cap company over big-cap company, HML is the excess return of value stock overgrowth stock, ϵ is the risk.

3.3 Expected Return of the Portfolio

The expected return of the portfolio is calculated by the sum of individual asset expected returns by proportion. The expected return of each stock is calculated by FF3F, so the equation is

$$R = \sum\nolimits_{i=1}^{n} p_i r_i \tag{4}$$

where R is the portfolio expected return, n is the number of stocks forming the portfolio, p_i is the proportion of stock i in the portfolio, r_i is the FF3F expected return of stock i.

3.4 Sharpe Ratio

Sharpe ratio is a widely used factor which can show the risk and return of one asset at the same time. Sharpe ratio represents the amount of excess return one can get when taking one more unit of risk. When the number is above 1, the return of the asset surpasses its volatility and when it is below 1, the risk is higher. Maximizing Sharpe ratio of a portfolio is one way to obtain a low-risk portfolio. Sharpe ratio can be calculated by

$$SharpeRatio = \frac{R_p - R_f}{\sigma_p} \tag{5}$$

where R_p is the return of portfolio, R_f is the risk-free rate and σ_p is the standard deviation of the excess return of the portfolio.

4 Results

The pension investment focuses on high return with low risk, so the portfolio is formed based on maximum Sharpe ratio. There will be two final portfolios with one investing all of the pension savings and one investing only 30% of the pension savings.

To mock the possible change in the pension savings, since the investment is Chinese Yuan invested in the US market, the rate of US dollars to Chinese Yuan of five years is taken. The expected return of pension savings is calculated by the average of the daily returns of exchange rate.

The expected returns of the stocks are calculated by FF3F model and results about the intercepts of regression and statistics are shown Table 2.

Table 2 shows that all three factors have positive correlation with the return of INTC stock. HML factor has minute effect on the return. The other two factors might have relatively equal effect on the stock return. The 95% confidence interval shows that Mkt-RF is the most likely to have a definite positive correlation with INTC return.

Table 3 shows that all three factors have positive correlation with the return of TXN stock. Mkt-RF has the greatest effect on stock return with the coefficient of it being 0.8508 and lower and upper 95% being 0.5913 and 1.1102. The coefficients of other two factors are only 0.3180 and 0.2322.

Table 4 shows that SMB has a negative correlation with the return of XLP and the coefficient is -0.5806 being in a negative 95% confidence interval. This result may be explained by the large-cap companies included in the fund which will change in different directions with the SMB factor. The Mkt-Rf factor has an obvious positive effect on the stock return.

Table 2. Regression results of INTC

	Coefficients	Standard error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.0062	0.0097	0.6415	0.5240	-0.0133	0.0257
Mkt-RF	0.4324	0.2036	2.1241	0.0383	0.02410	0.8407
SMB	0.4838	0.3540	1.3665	0.1775	-0.2263	1.1939
HML	0.1360	0.2297	0.5918	0.5565	-0.3248	0.5967

Table 3. Regression results of TXN

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.0090	0.0062	1.4553	0.151478	-0.0034	0.0214
Mkt-RF	0.8508	0.1294	6.5765	2.16E-08	0.5913	1.1102
SMB	0.3180	0.2250	1.4134	0.1634	-0.1333	0.7692
HML	0.2322	0.1460	1.5904	0.1177	-0.0606	0.5250

Table 4. Regression results of XLP

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-0.0012	0.0031	-0.3851	0.7017	-0.0074	0.0050
Mkt-RF	0.7063	0.0650	10.8740	4.14E-15	0.5760	0.8366
SMB	-0.5806	0.1130	-5.1396	4.05E-06	-0.8072	-0.3540
HML	0.1216	0.0733	1.6591	0.1030	-0.0254	0.2686

Table 5. Regression results of BRSVX

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.0047	0.0063	0.7412	0.4618	-0.0079	0.0172
Mkt-RF	1.0928	0.1315	8.3098	3.59E-11	0.8290	1.3566
SMB	1.1913	0.2287	5.2088	3.17E-06	0.7326	1.6500
HML	0.5926	0.1484	3.9931	0.0002	0.2949	0.8903

Table 6. Expected returns of the assets

	INTC	TXN	XLP	BRSVX	USD_CNY
Expected Return	0.0052	0.0081	0.0050	0.0127	0.0104

Table 5 shows that Mkt-Rf and SMB all have a significant positive correlation with BRSVX stock return. The largest coefficient 1.1913 is from SMB, because this mutual fund mainly chose large proportion of small-cap companies.

Using the regression results above and the average of exchange rate, the expected returns are calculated and shown in Table 6.

The goal of the portfolio is to have high return with low variance. According to the definition of Sharpe ratio, the proportion of the assets should be set maximizing the Sharpe ratio of the portfolio. To calculate the Sharpe ratio of the portfolio, covariance matrix is needed and is shown in Table 7.

The portfolio is made up of four stocks, but to control the different proportion of pension savings invested, pension is included to simplify the calculation. When all of the pension saving is invested, the weight of pension in the portfolio will be 0. When only 30% of the pension saving will be invested, the weight of pension in the portfolio will be 70%. The expected return of the portfolio can be calculated by the weight of the assets with the individual expected returns. Sharpe ratio can also be obtained by the expected return, covariance matrix and portfolio weight. To maximize Sharpe ratio, individual portfolio weight and covariance matrix are fixed and change the portfolio weights of the four assets until the maximum is found. The constraints in the optimization process are the sum of portfolio weight is 1 and pension weight cannot be changed. The results of

Table 7. Covariance matrix of the four assets and exchange rate

	INTC	TXN	XLP	BRSVX	USD_CNY
INTC	0.0056	0.0023	0.00030	0.0021	0.0056
TXN	0.0023	0.0040	0.0010	0.0031	0.0023
XLP	0.0003	0.0010	0.0015	0.0016	0.0003
BRSVX	0.0021	0.0031	0.0016	0.0076	0.0021
USD_CNY	0.0056	0.0023	0.0003	0.0021	0.0056

Table 8. Portfolio investing all of the pension savings

	INTC	TXN	XLP	BRSVX	PENSION
Portfolio Weight	0.0435	0.2169	0.4843	0.2553	0
Expected return	0.0077				
Variance	0.0021				
Standard dev	0.0460				
Sharpe Ratio	0.1671				

Table 9. Portfolio investing 30% of the pension savings

	INTC	TXN	XLP	BRSVX	PENSION
Portfolio Weight	0	0	0.0195	0.2805	0.7
Expected return	0.0109				
Variance	0.0042				
Standard dev	0.0649				
Sharpe Ratio	0.1685				

portfolio investing all of the pension savings and portfolio investing 30% of the pension savings are shown in Table 8 and Table 9.

It can be shown that the expected return of the portfolio investing 30% of the pension savings is lower than the expected return of BRSVX but are higher than the rest of the four assets. Its variance is higher than XLP and TXN but lower than INTC and BRSVX. The portfolio investing all of the pension savings has lower expected return than the one investing 30%, while its variance is lower than the one investing 30% and only higher than the variance of XLP. The Sharpe ratio of the portfolio investing all of the savings is higher than the one investing only part of the savings. However, the difference in Sharpe ratio is not significant, which may be explained by the volatility of the exchange rate of CNY to USD.

Since shorting is not considered, the second portfolio contains zero percent of INTC and TXN under the circumstance of maximizing Sharpe ratio. That is partly due to the higher variance of the two stocks over the other two funds.

5 Conclusion

The article looks into the portfolio investment of Chinese pension savings. This investment focuses on the specific time of post COVID era, which may affect the risks and returns of stocks in financial market. Using Chinese Yuan to invest in the US financial market is also a problem worth considering. First, the assets in the portfolio are chosen by analyzing the fields of the companies and risk diversification. INTC, TXN, XLP and BRSVX are chosen to form the portfolio. FF3F model calculates the expected returns. Then, the data of the four stocks helps calculate the Sharpe ratio and other information of the portfolio. The final portfolios are formed by maximizing Sharpe ratio. Different weights of the assets are obtained when investing all of the pension savings and only investing 30% of the pension savings. The results showed that only investing part of (30%) the pension savings may be a more reasonable investment choice. It also implies that it should be more careful when involving the stock of a company into the portfolio. The global pandemic shocked the financial market extensively, causing the stock prices to ascend and descend, so the variance of stocks may experience a rise. Therefore, thorough research of the company and the field it is in should be done before the investment. But the portfolio eliminates the risk compared to the risks of single assets.

The article only used the FF3F model to calculate the expected returns, more results may be gained by using other types of models.

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