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The Applicability of Time-varying Sharpe Ratio to Chinese Stock Market——Take CSI 300 Index as an Example

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Abstract. According to China's national conditions, this paper cites the factors related to the volatility of Shanghai and Shenzhen stock markets as explanatory variables and uses time-varying Sharpe ratio proposed by Robert Whitelaw to analyze the trend of CSI 300 index. The results show that the modified time-varying Sharpe ratio can predict the trend well, and the leading indication of the index's bottom reversal is more obvious. At the same time, the investment strategy constructed by using the ratio also achieves the desired profit. These results demonstrate the important role of time-varying Sharpe ratio in controlling risks and improving investment performance.

Introduction

At present, most of the researches on the volatility of Chinese stock market are based on macroeconomic factors, as gross national product (GNP), currency circulation, interest rate and so on. Although they can explain the fluctuation of stock market to some extent, the situation is too complicated to be explained well. There is a lack of predictive judgment. Time-varying Sharpe ratio proposed by Robert White law(1994)[1] solves this problem well and can be used to construct an effective investment strategy. However, this research is seldom studied in China.

Chinese stock market has not been established for a long time, and the research on its volatility is also in absence. Is it possible to use time-varying Sharpe ratio to predict the volatility trend and to construct a portfolio? This article mainly studies on this, and divides into five sections: the first is the introduction and the second introduces the model of time-varying Sharpe ratio. In section 3 and 4, we make the empirical analysis for Chinese stock market index to get the prediction of time-varying Sharpe ratio, then carry out out-of-sample analysis, and try to build an effective investment strategy. The last section is the summary of this paper.

The Brief Introduction of Time-Varying Sharpe ratio

For time-varying Sharpe ratio is based on Sharpe ratio, the study of time-varying Sharpe ratio should be started from the understanding of Sharpe ratio.

Sharpe Ratio

Sharpe ratio, presented in 1966 by William Sharpe[1], is a function using the mean and variance of the investment income to describe the investment strategy's performance. The formula is as follows:

$$S=\frac{E(\mathrm{r})-R_f}{\sigma}$$

Where S is Sharpe ratio, $E(\mathrm{r})$ is the portfolio's required rate of return, R_f is the risk-free rate of return and σ is the standard deviation of the portfolio's rate of return. The ratio is based on the capital asset pricing model and is often used to evaluate the performance of financial assets, which the core idea is very simple: as rational investors, we should choose the portfolio with the highest expected return under the same risk level, or the portfolio with the lowest risk level under the same expected rate of return; the expected rate of return should be greater than or equal to the risk-free rate of return. In theory, risk factors can be excluded when measuring the performance of a portfolio.

However, Sharpe ratio is not easy to be accurately measured because it is a function with mean and variance. It changes with the range of observations. That is, Sharpe ratio is time-varying which is directly related to time, and cannot be used to calculate the rate of return and the standard deviation in dependently within a period[3,4].Therefore, Robert Whitelaw(1994)[4] modified Sharpe ratio and proposed time-varying Sharpe ratio.

Time-varying Sharpe Ratio

Robert Whitelaw(1994)[1] selected four financial variables which have significant impacts on the average and volatility of S&P index yield as explanatory variables to set the model:

$$R_{t+1} - R_{ft} = X_t \beta_1 + \varepsilon_{1t+1}$$

$$\sqrt{\frac{\pi}{2}} |\varepsilon_{1t+1}| = X_t \beta_2 + \varepsilon_{2t+1}$$

In the model, R_{t+1} represents the yield of the S&P index in t+1 period, R_{ft} represents the risk-free interest rate in the American market, X_t is a matrix consisting of Baa-Aaainterest rate differential, Bills-Treasury bills interest rate differential, one-year treasury interest rate and dividend yield in t period, ε_{1t+1} and ε_{2t+1} are the residuals of the first equation and the second one respectively, and β_1 and β_2 are the regression coefficients of the equations.

Yi Tang, Robert Whitelaw(2011)[5]revised the explanatory variables in 2011. They believed the explanatory variable of Bills-Treasury bills interest rate differential had little effect on the average of the index yield, and the Baa-Aaainterest rate differential and dividend yield had little effect on the volatility of the index yield. Therefore, they excluded these variables. The new model is:

$$R_{t+1} - R_{ft} = X_{1t} \beta_1 + \varepsilon_{1t+1}$$

$$\sqrt{\frac{\pi}{2}} |\varepsilon_{1t+1}| = X_{2t} \beta_2 + \varepsilon_{2t+1}$$

Thus, the estimated time-varying Sharpe rate is:

$$\hat{S}_t = \frac{X_{1t} \hat{\beta}_1}{X_{2t} \hat{\beta}_2}$$

$\hat{\beta}_1$ and $\hat{\beta}_2$ are the estimated values of β_1 and β_2. Yi Tang and Robert Whitelaw analyzed U.S. economic data from 1953 to 2010. The calculated time varying Sharpe ratio can be used to judge the economic cycle well. At the same time, the authors use the ratio as timing selection. Four different investment strategies were set, and the return rate was significantly higher than that of the long-term holding index in the same period. The investment strategy was successful.

It is obvious that the importance of time-varying Sharpe ratio lies in the introduction of time, which use historical data to fit the regression equation, and will change with time and its trend can be predicted. It plays an important role in the market risk aversion.

The Application of Time-Varying Sharpe Ratio in Shanghai and Shenzhen Stock Market

Robert Whitelaw's time-varying Sharpe ratio is a study of the U. S. stock market, but China's economic environment is very different from the United States. Therefore, if we want to use the ratio in Chinese domestic market, it is necessary to modify it according to China's actual conditions.

Variable Selection

This paper uses time-varying Sharpe ratio to analyze the stock market in Shanghai and Shenzhen, selects three months benchmark deposit interest as the risk-free interest rate, and selects overnight data on Shanghai Interbank offered rate, Shanghai stock market price-earnings ratio and the Dow

Jones Index in the United States which have high correlations with the fluctuation of Shanghai and Shenzhen 300 Index constitute an explanatory variable vector group. Ji-Ping YANG, Yi-Jun FENG(2017)[6]study the impact of interest rate changing on the stock market volatility in different states, and conclude that the shock of the good news and the negative news in the same degree have the same effect on the volatility of Shanghai stock market in a rising state, while the negative news have greater impact on the volatility of Shanghai stock market in a state of decline. Qiao-Xin XIE and Liang-Rong SONG(2016)[7] believe that the interest rate mercerization increases the different opinions on the adjustment of interest rate trend in the market, which leads to the enhancement of the constancy of the stock market volatility effect. There is a long-term and stable equilibrium relationship between the Shanghai Stock Index and the Dow Jones Index of the United States, and the unidirectional guiding effect of the Dow Jones Index on the Shanghai Stock Index is significant (Wei-Jie WEI, Xiu-Fang WANG and Zhi-Yu XIA, 2016[8]; Xing-Feng ZHANG, 2016[9]). Hai-Ming LONG, Hao-Ming WU and Liu-SuoWU(2015)[10] consider that the average price-earnings ratio has a nonlinear effect on the stock index yield.

The Empirical Analysis

This paper uses Eviews software to carry on the empirical analysis, the sample data selection time is from January 4th 2007 to December 31st 2013, and the time of data selection outside the sample is from January 2nd 2014 to December 30th 2016, in which the overnight data on Shanghai Interbank offered rate is from shibor official website, the Shanghai Stock Market Index and the Dow Jones Index of the United States are taken from the Wanda database that the dates with only one or two data are excluded (the rest is 1699 trading days),and the three-month benchmark deposit interest is taken from the official website of the people's Bank of China.

This paper calculates the daily yieldrate of CSI 300 index, the Dow Jones Index and the three-month benchmark deposit interest at first, then make the ADF test on the excess return rate(futrue-r)(the excess return rate =Shanghai and Shenzhen 300 index yield–risk free rate of return), Dow Jones index yield(dow), the overnight data on Shanghai Interbank offered rate(shibor) and the average price-earnings ratio of 300 index in Shanghai and Shenzhen(pe).From the results, we could see that the variables future-r, dow and shiborpass the ADF test, but the variable pe has no unique unit root, which is a non-stationary time series and has not passed the test. Therefore, we take the first order difference of pe (denoted as D(pe)) to carry out the ADF test and it passes. The results of the test are shown in Table 1.

Table 1 the ADF Test of the Explanatory Variable

	future-r	dow	shibor	pe	D(pe)	Divi_shibor
t-statistic	-49.42679	-58.73241	-4.307108	-1.139707	-50.19199	-3.203903
Prob.	0.0001	0.0001	0.0004	0.7021	0.0001	0.0200
1% level	-3.432677	-3.432676	-3.432692	-3.432676	-3.432677	-3.434000
5% level	-2.862454	-2.862453	-2.862460	-2.862453	-2.862454	-2.863039
10% level	-2.567301	-2.567301	-2.567305	-2.567301	-2.567301	-2.567615

We continue the co-integration analysis of variables future-r, dow, shibor and D(pe): for the variable dow, the T test statistic of its regression coefficient is significant; the regression coefficient of variable shibor has not passed the co integration test. When we take the reciprocal form of shibor(recorded as Divi_shibor), the t test statistic of its regression coefficient is obvious. The ADF test of Divi_shibor is shown in Table 1. Neither the regression coefficient of D(pe) nor its other deformation has passed the cointegration test. So we removed the variable D(pe) and obtained the regression equation as follows (for the results of the analysis, see Table 2):

$$future - r = \text{-}0.002023 + 0.004084 * divi\_shibor + 0.185618 * dow + resid01$$

Table 2 the Results of Co-integration Analysis 1

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	-0.002023	0.001061	-1.907551	0.0566
dow	0.185618	0.028323	6.553502	0.0000
Divi_shibor	0.004084	0.001797	2.272261	0.0232
R^2	0.027722		**F-statistic**	24.17890
Adjusted R^2	0.026576		**Prob**	0.000000
DW	2.010020			

When making the co-integration analysis of the residual resid01 of the obtained regression equation(the ADF test of the residual resid01 is shown in Table 3), we find that the regression coefficients of the variables Divi_shibor and D(pe) have passed the test, while the regression coefficients of variable dow and its other deformation has not passed the test. Therefore, in the regression analysis of residual resid01, we remove the variable dow and obtain the regression equation as follows (see Table 4 for the analysis results):

$$\sqrt{\frac{\pi}{2}} resid01 = 0.015331 + 0.004031 * Divi\_shibor - 0.002466 * D(pe) + resid02$$

Table 3the ADF Test of Residual Resid01

	t-statistic	**Prob.**	**1% level**	**5% level**	**10% level**
Resid01	-41.38959	0.0000	-3.433998	-2.863038	-2.567615

Table 4the Results of Co-integration Analysis 2

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	0.015331	0.000922	16.63487	0.0000
Divi_shibor	0.004031	0.001561	2.582458	0.0099
D(pe)	-0.002466	0.000796	-3.096159	0.0020
R^2	0.009085		**F-statistic**	7.774942
Adjusted R^2	0.007917		**Prob**	0.000435
DW	1.730198			

From the above two regression equations we can easily calculate the time-varying Sharpe rate:

$$S = \frac{-0.002023 + 0.004084 * divi\_shibor + 0.185618 * dow}{0.015331 + 0.004031 * Divi\_shibor - 0.002466 * D(pe)}$$

We use the formula to calculate the time-varying Sharpe rate for each trading day between January 2nd 2014 and December 30th 2016. After noise reduction, the data are compared with the trend of CSI 300 index during this period. The results are shown in figure 1.

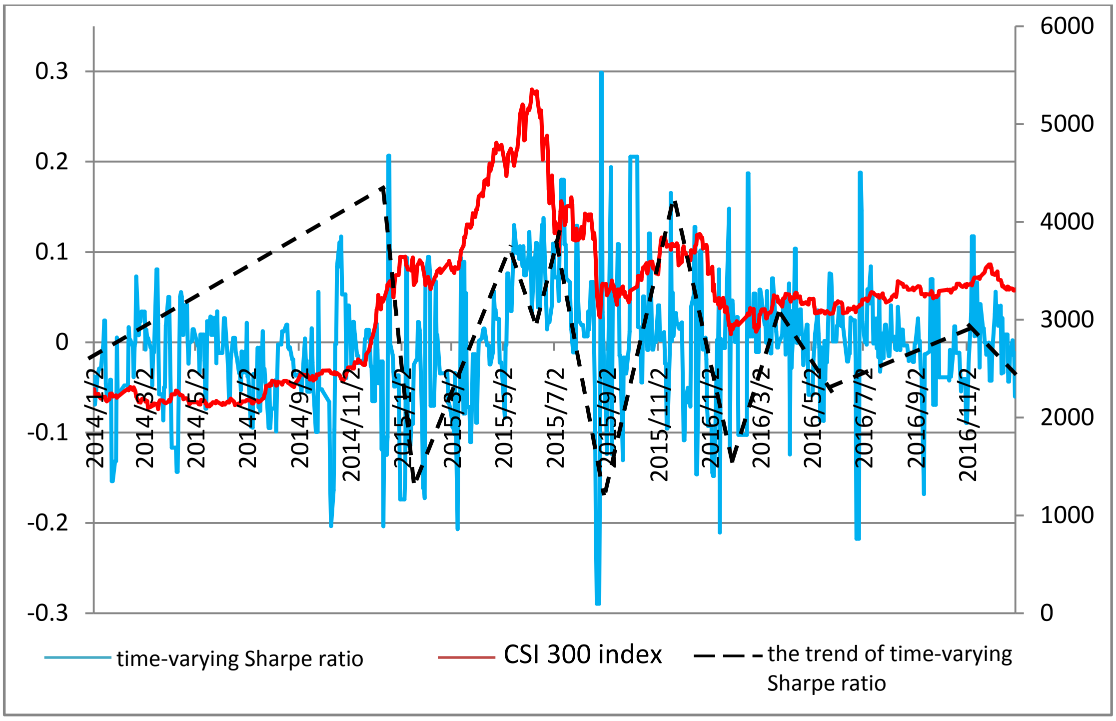

Fig. 1 Time-varying Sharpe Ratio and CSI 300 Index

It can be clearly seen from figure 1 that time-varying Sharpe ratio has a certain leading effect on the Shanghai-Shenzhen 300 index: whenever time-varying Sharpe ratio reaches a high level, the Shanghai-Shenzhen 300 index also reaches a high level later;and each time after time-varying Sharpe ratio fell, the Shanghai and Shenzhen 300 index will also have a corresponding decline; the leading role of bottom inversion is more obvious. Therefore, when forecasting the trend of index with time-varying sharpe ratio, we should pay more attention to the bottom inversion. It has important meaning to control risk.

The Application of Time-Varying Sharpe Ratio in Investment

Without taking the various costs incurred in the transaction into account, this paper takes CSI 300 index as the investment target to construct the investment strategy and compares the cumulative excess return rate of investment strategy with the cumulative excess return rate produced by the long-term holding index. The data are selected from January 2nd 2014 to December 30th 2016.

When making the timing selection to CSI 300 index by using time-varying Sharpe ratio, we need to determine a buying and selling threshold. We set this threshold to x, which corresponds to time-varying Sharpe ratio. From the figure 1, we could see that most of time-varying Sharpe ratios fall within the range of [-0.2, 0.2]. Therefore, in the [-0.2, 0.2] interval, we take an x value at every 0.01 (total 41 values), and corresponding to each x value we will get an investment strategy: when time-varying Sharpe ratiogoes up through x, we hold CSI 300 index; we sell CSI 300 index when time-varying Sharpe ratiogoes down through x. So which of these 41 investment strategies is performing best? Let's evaluate them with Sharpe ratio. As we can see from the above, Sharpe ratio can be used to measure the return and risk of investment strategy. While the higher the S is, the greater the return of the portfolio is at a given risk or the lower the risk is at a given return, so the investment strategy has better performance. And while the lower the S is, the less the return of the portfolio is at a given risk or the higher the risk is at a given return, so the investment strategy has worse performance. We use this formula to calculate the S values of these 41 strategies, and the results are shown in Table 5.

Table 5 the Performance of Investment Strategies

threshold x	**Sharpe ratio**	**threshold x**	**Sharpe ratio**
0.2	1.059059	-0.01	0.432046
0.19	1.180249	-0.02	0.672599
0.18	1.151508	-0.03	0.627122
0.17	0.500077	-0.04	0.705272
0.16	0.604692	-0.05	0.746545
0.15	0.604692	-0.06	1.002043
0.14	0.679973	-0.07	1.026928
0.13	0.308127	-0.08	0.984049
0.12	0.476708	-0.09	0.975537
0.11	0.506293	-0.1	0.89665
0.1	0.149895	-0.11	1.001251
0.09	0.357708	-0.12	1.047653
0.08	0.079707	-0.13	1.072604
0.07	0.212637	-0.14	1.034643
0.06	0.059861	-0.15	0.883006
0.05	0.09518	-0.16	0.869341
0.04	0.278141	-0.17	0.833339
0.03	0.287396	-0.18	0.805943
0.02	0.416839	-0.19	0.805943
0.01	0.387557	-0.2	0.805943
0	0.566945		

Table 6 the Screening of the Optimal Buying and Selling Thresholds

Threshold	**Sharpe Ratio**	**Holding Time(Day)**	**Cumulative Excess Return**	**More than the Continuous Holding Index**
-0.11	1.001251	689	72.90%	63.39%
-0.06	1.002043	617	66.53%	49.11%
-0.07	1.026928	632	70.25%	57.46%
-0.14	1.034643	706	76.92%	72.40%
-0.12	1.047653	700	77.67%	74.08%
0.2	1.059059	6	10.95%	-75.45%
-0.13	1.072604	703	79.99%	79.29%
0.18	1.151508	11	12.60%	-71.76%
0.19	1.180249	7	12.91%	-71.07%
Continuous Holding Index	**0.620594**	**733**	**44.62%**	——

Next, we select the Sharp ratios whose threshold are greater than 1 in Table 5 and compare the holding time and the cumulative excess return of their corresponding investment strategies. We find that when the threshold is -0.13, the corresponding investment strategy has the highest cumulative excess return, which is 79.99% and is 79.29% higher than the continuous holding index, and the Sharpe value and the holding time of the strategy are both ideal. Therefore, we choose the time-varying Sharp ratio -0.13 as the optimal buying and selling threshold. The corresponding investment strategy is as follows: when time-varying Sharpe ratio is greater than or equal to -0.13,we buy CSI 300 index; when time-varying Sharpe ratio is less than -0.13,we sell CSI 300 index. Besides, when time-varying Sharpe ratio is -0.12 or -0.14,the cumulative excess return, Sharpe ratio and the holding time of the corresponding investment strategies are well, of which the respective cumulative excess returns are 74.08% and 72.40% higher than the continuous holding index.(The results are shown in Table 6)

Conclusion

Time-varying Sharpe ratio is an important development of Sharpe ratio. We verified the applicability of time-varying Sharpe ratio in China, whose change is ahead of the volatility of the stock market index. In comparison with the trend of CSI 300 indexes, we find that the high of time-varying Sharpe ratio appears earlier than the peak of CSI 300 index, which also starts to show a downward trend soon after time-varying Sharpe ratio fall, and the lead on the index's downward trend is more significant. It also reflects the importance of time-varying Sharpe ratio in controlling investment risk. At the same time, this paper combines Sharpe ratio, the cumulative excess return rate and the holding time to choose time-varying Sharpe ratio as the optimal buying and selling threshold to construct the investment strategy for CSI 300 index. The cumulative excess return rate obtained bythe strategy is nearly 80% higher than that obtained by the persistent holding index, which indicates that the ratio is successfully used as a timing indicator in investment strategy.

Thus, time-varying Sharpe ratio has been successful both as a predictor of the index trend and as a timing indicator to construct an investment strategy. However, could it be used to observe the economic situation? Or are there other wider uses? These problems are worthy of our further study.

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