Evaluation of Stock Returns of Alpha-Factor Selection Strategy Based on Fama-French Three-Factor Model

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Abstract. Fama-French model is a classic model for predicting stock returns. This paper proposed a new quantitative trading strategy based on the classic multi-factor selection strategy and the Fama-French three-factor model. The strategy uses the model to extract the intercept term in its fitting model. The study uses the S&P500 dataset to simulate the strategy in two time periods, 2000 to 2010 and 2012 to 2022, that these two time periods include two special periods separately, the financial crisis and the new crown epidemic. The result shows that the model cannot predict the intercept value effectively. This original strategy made 0.3% and -2.11% yearly returns with 0.08 and -0.2 Sharpe ratios in the two datasets. Compared to the same time periods on the benchmark (equal-weighted portfolio), equal-weighted portfolios have 2.49% and 9.92% with 0.23 and 0.83 Sharpe ratios in both two datasets. However, using a long-only alpha strategy can improve the performance of both two datasets significantly. Long-only strategy made 9.12% and 18.16% yearly returns with 0.45 and 0.83 Sharpe ratios. Long-only strategy still carries a lot of risks and is significantly influenced by the market situation.

Keywords: Fama-French Three-Factor Model · Alpha · S&P500

1 Introduction

After the conclusion of the Quantitative Portfolio Management Project, this paper proposed a new strategy based on the existing classic quantitative strategy. This quantitative trading strategy is based on the Fama-French Three-Factor model. The strategy determines the portfolio by fitting the intercept terms of the model.

In that case, this paper assumed that the Fama-French three-factor model is completely valid. Li and Cheng found that the Fama-French three-factor model made a better performance than CAPM [1]. Zhang considered that in extreme cases after the outbreak of the new crown epidemic, the Fama-French three-factor models can still explain the expected returns of individual stocks of the constituents of the Shanghai Stock Exchange 50 Index in China [2]. In addition, Wang's results indicate that the factor values obtained by fitting the model can explain the risk premium effectively [3]. Hence, the assumption of the model used in this paper make economic sense. However, Mohammad used the

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model to predict cross-sections of the average portfolio returns of the size/book market cap portfolio of companies listed and traded on the ASE between 2002 and 2018, resulting in a slight deviation between the true and actual values [4]. The result of this strategy will measure the effectiveness of the model used in this paper to some extent.

The intercept term from the model presents that the current price of the stock deviates from the equilibrium price. Mateus and Todorovic showed by testing UK stocks that the stock's actual intercept value was higher than the alpha implied by fitting the model [5]. Therefore, the alpha in the Fama-French model may not accurate. Lajbcygier and Ooi also explicitly pointed out that the alpha estimation of this model is likely biased and may lead to incorrect conclusions in predictions [6]. Fabozzi and Konstantinov found that alpha is time-varying and opposed with the appearance before the global financial crisis, alpha fluctuates greatly and is in the short term [7]. In this paper, we make the initial condition with fewer environmental impact factors, by assuming that the Fama-French three-factor model is completely valid. In this case, the alpha is completely valid as well. When the alpha is negative, it illustrates that the stock yield is below the equilibrium level, and the stock price is undervalued. When the alpha is positive, it illustrates that the stock yield is above the equilibrium level. The strategy uses negated alpha to decide the weight of the portfolio. Considering about the effectiveness of the Fama-French model, this paper come up a new calculate method to decide the weight with alpha consideration based on the above strategy.

The author has already roughly tested this quantitative trading strategy with S&P500 from 2010 to 2020. The result shows that the strategy cannot perform well in these datasets. The strategy with alpha consideration cannot perform well in these datasets with equal result as the original strategy. However, when removing short from this strategy, i.e. long-only strategy, the strategy has significant improvement. To test whether this result has representative or just a special case, this paper tested the strategy with other datasets.

It is worth mentioning that there was a financial crisis in 2008 and the coronavirus pandemic from 2019. Both two periods have significant difference on global finance. Liu, Carporin, and Paterlini illustrated that the financial crisis of 2008 and the coronavirus pandemic in recent years have had a significant impact on the secondary market [8]. Hence, performances of the strategies in this paper would be influenced by the 2008 financial crisis and the coronavirus pandemic. Additionally, there are impacts on the market. By Dima and Dinca's study, among the external factors that influence secondary market volatility, inflation has the greatest impact, and commercial and industrial loans have a small (albeit significant) impact [9]. Most companies in the dataset we use are big companies so the two special periods would be less effected in this dataset. Matousek, Panopoulou, and Papachristopoulou adopted that Well-capitalized financial firms are less affected under unstable policies and during periods of severe market downturns. Not only that, in the special period, the companies have requirements to face financing requirements that cannot be underestimated [10].

2 Methods

2.1 Data Source and Basic Data Processing

The dataset in this paper is S&P500 Index, which is a stock index that records 500 publicly traded companies in the United States. The datasets include daily-return on 500 companies in the United States from 2000 to 2023. This paper split the datasets into two parts, the first period is from 2000 to 2010, the second period is from 2010 to 2020.

To put the strategy to the test extensively, this study keeps all the stocks in the data, i.e., stocks of five hundred companies. Some of these companies went bankrupt within those 23 years and no longer have daily returns in the data after that. This research also set the daily return after each company goes bankrupt to zero, which is obviously reasonable and does not affect the results.

2.2 Research Method

This research uses Ordinary Least Square method to do the linear regression and uses Fama-French three-factor model to predict the data. This research uses Python code to simulate the trading strategy presented in this paper. For Ordinary Least Square method, the main formula is as follow:

$$\hat{\beta} = \left(X^T X\right)^{-1} X^T Y \tag{1}$$

This research uses a function in Python called "OLS" in "statsmodels.api" package to calculate the estimated value of the intercept (alpha) and betas with ordinary least square method automatically. For Fama-French three-factor model, its formula is:

$$R_t - R_f = \alpha + \beta * \left(R_m - R_f\right) + \beta_{SMB} * R_{SMB} + \beta_{HML} * R_{HML} + \epsilon \tag{2}$$

$R_t - R_f$ is the market risk premium. α is the intercept of the fitted model, which is the main core of the strategy in this research. The rest of the model, i.e., each beta in the formula, would not be explained in the paper because this research only examines the role of alpha in the model, and the paper has cited relevant literature in the Introduction section to prove the effectiveness of the model. Additionally, this model is very classic and common.

In the above formula of Ordinary Least Square method: $\hat{\beta}$ is a vector:

$$\overrightarrow{n} = (\alpha, \beta, \beta_{SMB}, \beta_{HML}) \tag{3}$$

X is a matrix:

$$X = \left(I, (R_m - R_f), R_{SMB}, R_{HML}\right) \tag{4}$$

where I is a vector which all the element in it is one, and $(R_m - R_f)$, R_{SMB}, R_{HML} are all vectors with its values defined by Eugene Fama and Kenneth French (two guys who came up with the model). Y is a vector of $R_t - R_f$.

2.3 Alpha Trading Strategy

Fundamentals and principles of the strategies: Use daily return in the train datasets to fit the Fama-French model, get the intercept (alpha) value, use alpha value to decide the portfolio weight in the test datasets next to each train datasets. This research uses every 20 trading days as a train period to test next 60 trading days, and do this again and again until the 10-year datasets finished its simulation.

This research includes 4 strategies which are all based on the fitted alpha value from model. In order to make the following description more concise, this paper gives reasonable names to all four strategies. They are: Original Strategy, Original Strategy + P-value consideration, Long-only Strategy, Long-only Strategy + P-value consideration. The differences between the 4 strategies are just how to decide its portfolio weight based on the alpha value. All strategies in this research normalized the weights such as that the sum of the absolute value of all weights is one per day.

The first Strategy is Original Strategy uses negated alpha directly as portfolio weight. The second Strategy is Original Strategy + P-value consideration: This research is based on the model, what if even the model cannot predict the intercept value well? This strategy considers the p-value of the alpha. On common principle, every stock which its alpha with p-value bigger than 0.05 should be removed. However, removing the stock directly with the condition above may make the portfolio weight in a whole 60-day test datasets extremely and uncontrollably simple. To avoid removing a stock directly, this strategy calculates its portfolio weight as follow: weight $= -\alpha * (1 - p\text{-}value)$. In this case, this strategy only changes the ratio of the weight based on the p-value of the alpha for each stock.

The third Strategy is Long-only Strategy is purposed with no economical reason. However, long-only strategy based on the alpha value performances much better than a) and b) strategies. As the name of the strategy, this strategy removes stocks which has positive alpha (this research assume that negated alpha can predict the return, the reason has illustrated in Introduction) in the portfolio. The fourth Strategy is Long-only Strategy + P-value consideration: The method of p-value consideration is same as the Original Strategy + P-value consideration strategy. Hence, this strategy is Long-only Strategy with P-value consideration.

3 Results and Discussion

3.1 Time Period: 2000–2010

For the Original Strategy. The yearly Sharpe ratio is 0.08. The yearly return is 0.30%. The max drawdown is 0.33. During the 2000 to 2010 time period, the Original Strategy cannot perform well in this dataset. The yearly Sharpe ratio is 0.08 with a 0.30% yearly return, which is very low. Overall, the strategy fluctuated greatly, and it seemed to perform very well at the beginning of 2003 and maintained its earnings until 2005, but by 2010 it had lost money to almost the same level as the principal. Hence, this strategy carries a lot of risks and cannot perform well, as shown in Fig. 1.

For the Original Strategy + P-value consideration. The yearly Sharpe ratio is 0.13. The yearly return is 0.86%. The max drawdown is 0.33. After adding the consideration

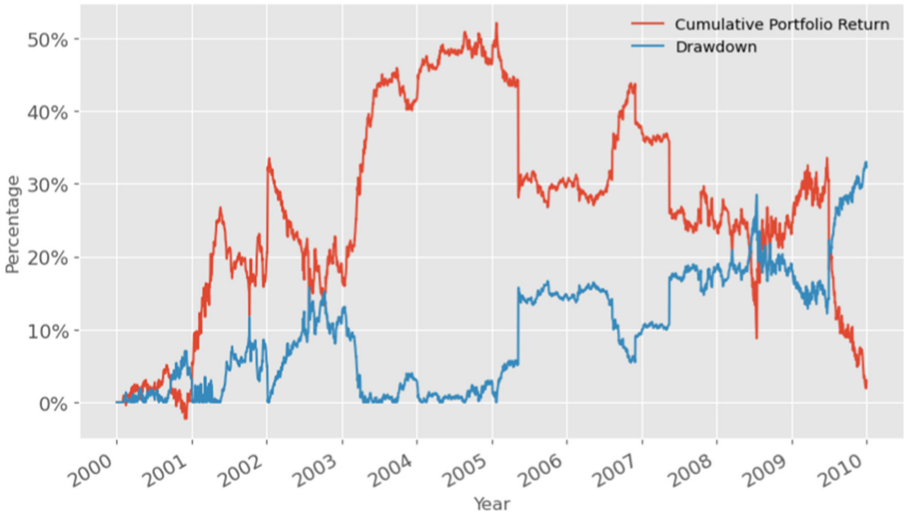

Fig. 1. Original strategy during 2000 to 2010 on S&P500.

of the p-value of the alpha, the yearly Sharpe ratio rises to 0.13, which is still very low but has an improvement compared to the Original Strategy, as shwon in Fig. 2.

It can be seen that the performance of this strategy and the timing of its fluctuations are almost identical to the original strategy. The difference is that when the portfolio ratio is reallocated in the strategy according to the p-value of alpha in the fitted model, the volatility of this portfolio is reduced, which reduces the risk of the entire portfolio by a small amount. In this case, the Sharpe ratio is improved, and at the same time,

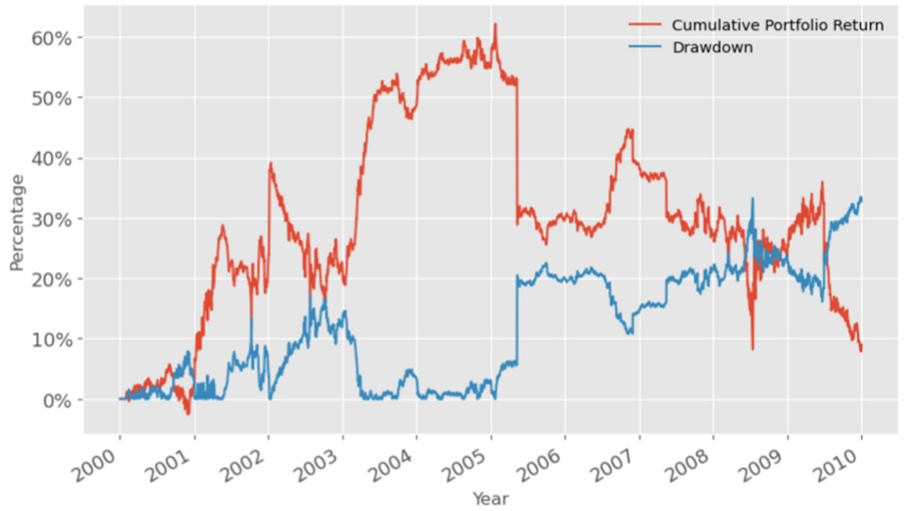

Fig. 2. Original strategy with p-value consideration during 2000 to 2010 on S&P500.

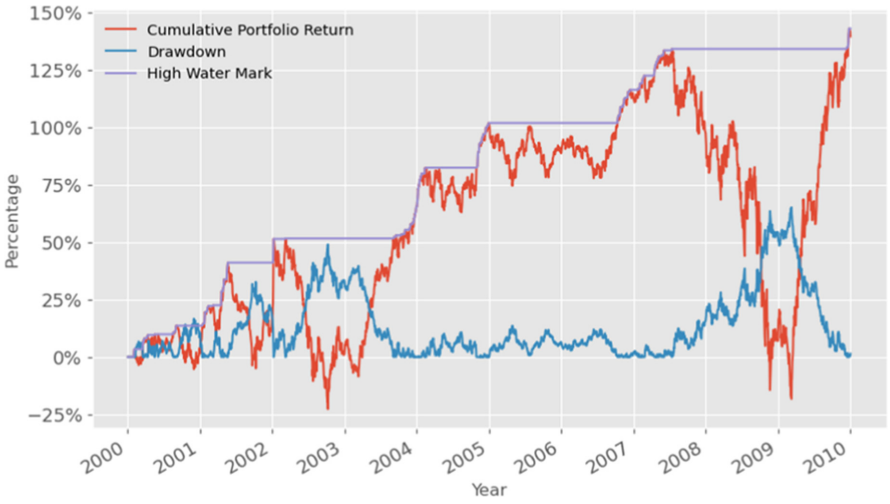

Fig. 3. Long-only strategy during 2000 to 2010 on S&P500.

p-value consideration somewhat improves the accuracy of fitting the model, allowing the portfolio to be slightly protected from losses around 2010. Therefore, this strategy performed better than the original strategy.

For the Long-only Strategy. The yearly Sharpe ratio is 0.45. The yearly return is 9.12%. The max drawdown is 0.65. The Long-only strategy has a much higher return than the previous two strategies. It can get a return of 9.12% per year, but the Sharpe ratio remains low at 0.45. As can be seen from Fig. 2, in 2002 and 2008, this portfolio suffered huge losses, even losses to negative profits. There is no doubt that these two losses make the overall volatility higher, resulting in a high portfolio risk and a lower Sharpe ratio, as shown in Fig. 3.

For the Long-only Strategy + P-value consideration, the yearly Sharpe ratio is 0.45. The yearly return is 9.10%. The max drawdown is 0.66. Not surprisingly, with the addition of p-value consideration, the overall performance of this strategy is almost the same as the long-only strategy. However, compare to the difference between the Original strategy and the Original Strategy + P-value consideration, P-value consideration seems does not work in long-only strategy, as shown in Fig. 4.

3.2 Time Period: 2012–2022

For the Original Strategy. The yearly Sharpe ratio is -0.20. The yearly return is -2.11%. The max drawdown is 0.43.

The original strategy's portfolio was consistently loss-making, and the net worth curve was ugly, and it was clear that the model was unable to effectively predict return for nearly a decade. Between late 2013 and early 2014, the portfolio lost a lot of money, and the loss situation improved a little around 2010. Compared to the performance of this strategy from 2000 to 2010, the performance of the original strategy in the two periods is very different, as shown in Fig. 5.

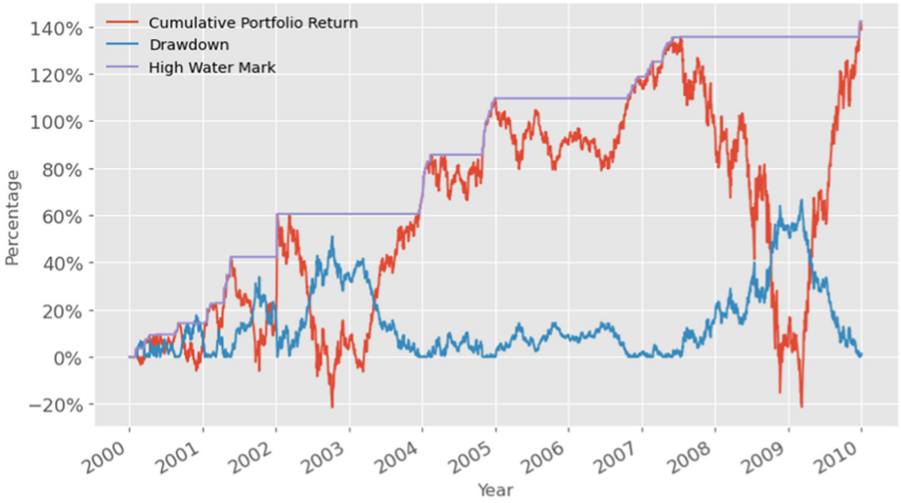

Fig. 4. Long-only strategy with p-value consideration during 2000 to 2010 on S&P500.

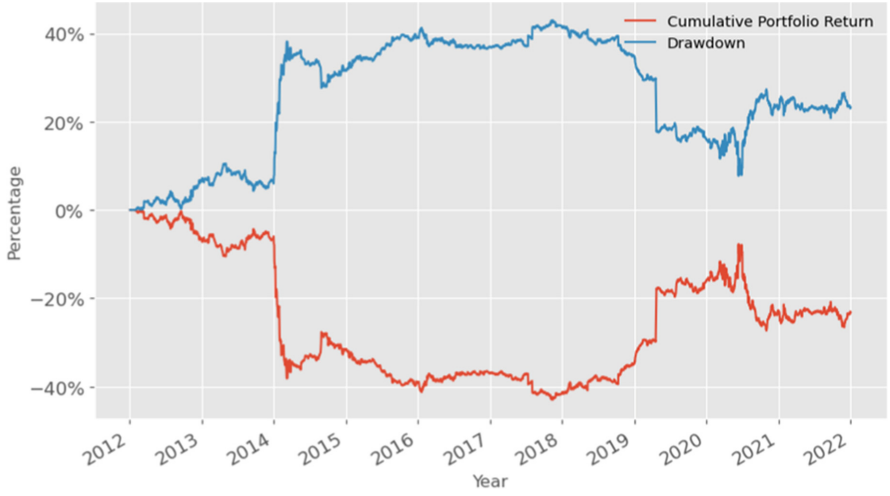

Fig. 5. Original strategy during 2012 to 2022 on S&P500.

For the "Original Strategy + P-value consideration". The yearly Sharpe ratio is -0.30. The yearly return is -2.76%. The max drawdown is 0.46. In the 2012–2022 dataset, redistributing the proportion of the portfolio by considering the p-value of the alpha in the fitted model surprisingly made the strategy perform worse. However, p-value consideration cannot change the perform of the original strategy significantly, as shown in Fig. 6.

For the "Long-only strategy". The yearly Sharpe ratio is 0.83. The yearly return is 18.16%. The max drawdown is 0.43, as shown in Fig. 7.

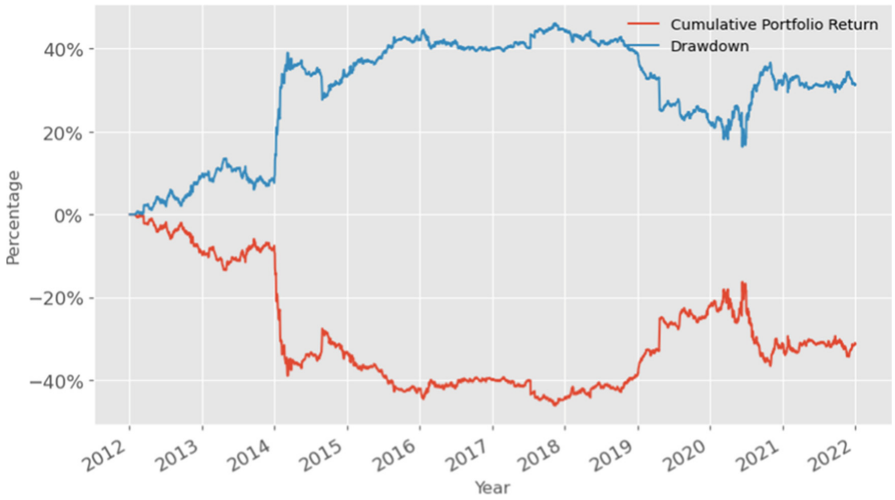

Fig. 6. Original strategy during 2012 to 2022 on S&P500.

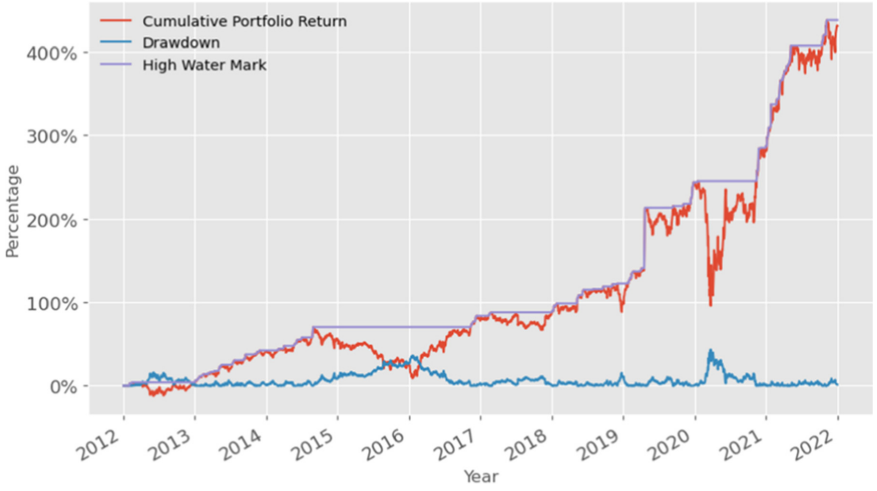

Fig. 7. Long-only strategy during 2012 to 2022 on S&P500.

The performance of the long-only strategy in the period from 2012 to 2022 is considerable, and it has to be said that without such good performance, the strategy performance of this period will not be included in this paper. It has an 18.16% yearly return which a Sharpe ratio is 0.83. Compared to the original strategy equity curve over the same period, the only part that can be seen as a common denominator is the change in the equity curve in 2020. In 2020, both the losses of the original strategy and the profits of the long-only strategy have significantly changed.

For the "Long-only strategy + P-value consideration". The yearly Sharpe ratio is 0.80. The yearly return is 16.89%. The max drawdown is 0.43. This strategy made a

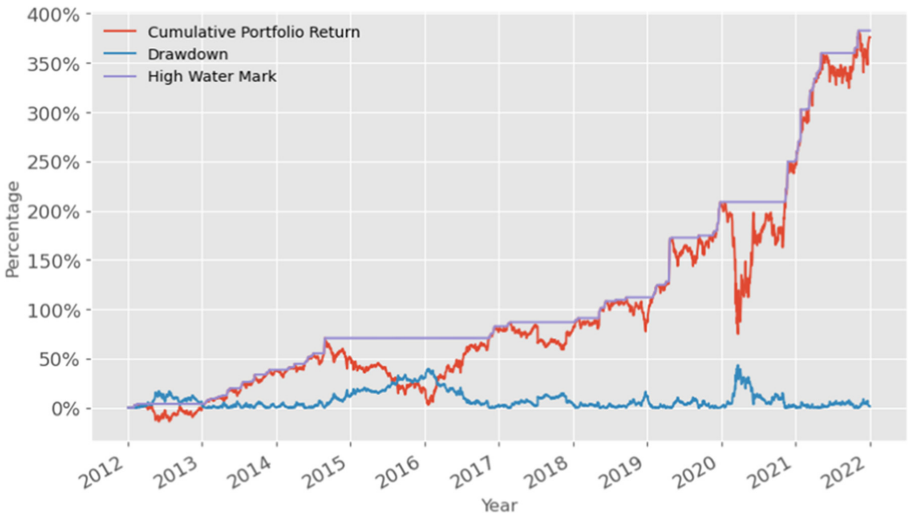

Fig. 8. Long-only strategy with p-value consideration during 2012 to 2022 on S&P500.

16.89% yearly return which has a 0.80 Sharpe ratio from 2012 to 2022. Compared to the long-only strategy over the same period, redistributing the proportion of the portfolio by considering the p-value of the alpha in the fitted model cannot improve the strategy significantly. As can be seen from Fig. 7, between late 2005 and early 2006, p-value considerations increased losses during this period, as in Fig. 8.

To measure whether the four strategies performed well and were good enough over two different periods, the study will compare these data with benchmark simulations over the same period in the same datasets. During the period from 2000 to 2010, the equal-weighted portfolio has a 0.23 yearly Sharpe ratio with a 2.49% yearly return. During the period from 2012 to 2022, the equal-weighted portfolio has a 0.83 yearly Sharpe ratio with a 9.92% yearly return.

Hence, the original strategy performs terribly with a low Sharpe ratio and perform varies significantly over different periods. Based on the previous equity curve, the long-only strategy clearly shows the situation during the financial crisis of 2008. The original strategy behaved very differently over two different periods. This illustrates the original strategy, that is, the model cannot effectively predict intercept terms in special periods.

4 Conclusion

This research comes up with a new strategy based on the Fama-French three-factor model and the classic strategies. The strategy uses the ordinary least squares method to fit the model and obtains the current price of the stock that deviates from the equilibrium price by fitting the intercept term of the model. Under the test of the S&P500 dataset, this study obtained the simulation results of trading strategies for the 10 years 2000–2010 and 2012–2022. It turns out that the model cannot predict the value of the intercept term of the stock return well. This study also takes how confident the model itself is

in predicting the intercept term of return into account. By examining the p-value of the intercept term part of the fitted model and reassigning the portfolio weight ratio, the results show that this does not significantly improve the strategy. However, based on this strategy, keeping only the buy part (long-only strategy), and thus obtaining a new portfolio can significantly increase the return of the strategy. It cannot be ignored that under the 2008 financial crisis, all the strategic results obtained in the study were greatly affected by this. Not only that, the strategy of predicting return based on the model (alpha) always has a Sharpe ratio that is not high enough, indicating that the strategy carries great risks.

5. References

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