Empirical Research on Pharmaceutical Industry Returns Based on Fama-French Three-Factor Model

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Abstract—The Covid-19 pandemic swept the world in early 2020, which not only aroused widespread social concern but also made the financial market shocked and made investors panic, while the pharmaceutical industry received high attention. In this paper, nearly 300 companies in China's pharmaceutical industry are studied and divided into six portfolios based on market capitalization size and book-to-market ratio, and the Fame-French three-factor model is applied to regression analysis of the full sample, before, and after the outbreak of Covid-19 pandemic return segments. The results show that the three-factor model has good explanatory power on stock returns in the Chinese pharmaceutical industry, and the market factor, size factor, and book-to-market ratio factor all have an impact on stock returns in the pharmaceutical industry. Among them, the market factor has the most significant impact. However, the explanatory power after the Covid-19 pandemic is not as strong as before the Covid-19 pandemic, which may be due to various reasons such as the instability of investor sentiment and the intricacies of the market environment, which increase the uncertainty of healthcare stock returns after the Covid-19 pandemic. Fewer studies have analyzed and studied the impact of stock returns in the pharmaceutical industry using multiple perspectives, and this paper helps investors establish a clear investment logic to decide their commitment to the pharmaceutical industry.

Keywords-pharmaceutical industry; stock returns; Fama-French three-factor

1 INTRODUCTION

As an important part of the stock market, pharmaceutical and biological stocks are characterized by rigid demand, non-cyclicality, and low sensitivity, and have shown good risk resistance in the past several stock market crashes. The "13th Five-Year Plan" for the pharmaceutical industry, which mentions the layout of "Health China 2030", means that China will include the pharmaceutical industry in the national key construction plan. 2018 annual pharmaceutical industry enterprise revenue, net profit growth rate of 20.3% and 13.52%, respectively. In 2018, the year-on-year growth rates of revenue and net profit of pharmaceutical industry enterprises were 20.3% and 13.52%, indicating the rapid growth momentum of the industry. However, the shock of the Covid-19 pandemic has had an effect on the stock returns of the pharmaceutical industry, and by comparing the explanatory power of the three-factor model on stock returns before and after the Covid-19 pandemic, we can come to judge investors' attention to event-

FFIT 2022, October 28-30, Shenzhen, People's Republic of China

DOI 10.4108/eai.28-10-2022.2328423

related concept stocks in the face of major uncertainty event shocks and the impact of the current market situation on stock returns.

This paper empirically studies Chinese pharmaceutical sector based on the theory of quantitative value investment and realizes the value investment stock selection and dynamic portfolio management of the pharmaceutical industry through the Fama-French three-factor model. Second, the stocks are divided into six groups based on market capitalization and book-to-market ratio, and calculating the weighted monthly returns of each group; then the size factor (SMB), market factor (MKT), and value factor (HML) are calculated based on the obtained weighted portfolio monthly return data, and the correlation between candidate factors and returns is tested. The correlation between the candidate factors and the returns is tested to find the effective factors for us. After that, we further eliminate the redundant factors and apply the correlation test of multivariate grouping to bring in the data of the yield evaluation cycle to get an effective portfolio. Finally, this paper analyzes the results of multi-factor stock selection and its logic. Based on the results, this paper concludes that the three-factor model has better explanatory power for stock returns in the Chinese pharmaceutical industry.

The pharmaceutical industry has a good prospect. However, there are few quantitative analyses and specialized studies on the pharmaceutical industry in China, so this paper studies the value of listed pharmaceutical companies in the context of the "new health care reform" to supplement the research gaps in this field, and to test the impact of the Covid-19 pandemic on the pharmaceutical stock market, and to guide future investment activities. To avoid the risk and loss of those who blindly follow the hot stocks, we can guide the better allocation of resources to the pharmaceutical industry.

In the field of capital markets, asset pricing has been a hot topic of interest. Portfolio theory was first proposed by Markowitz, using mean-variance analysis for optimal portfolios, arguing that unsystematic risk can be reduced by portfolios [1]. In the empirical study by William Sharpe and John Lintner, the CAPM, as a one-factor model, argued that when there are no frictions in the market, the return on stocks is only related to market risk, and thus proposed the Capital Asset Pricing Model (CAPM), which was unanimously accepted by the public at the time [2,3]. A related study later found that systematic risk does not fully explain stock returns, and Roll argued that there are an unknown number of other factors that affect stock returns, and thus the Arbitrage Pricing Theory (APT) was proposed to fill the gap in the Capital Asset Pricing Model [4]. Subsequently, Fama and French conducted further research on the factors affecting stock returns and systematically examined the factors other than systematic risk factors that may have an impact on expected stock returns [5]. The results show that β values are difficult to explain the variability among stock returns, the market asset mix factor($R_{m-}R_f$), size factor (SMB), and book-to-market ratio factor (HML) are better able to explain the excess return of the portfolio and are confirmed by scholars [6].

In early 2020, an unprecedented virus suddenly broke out in full force in Wuhan, spreading rapidly to various cities, and the Chinese government quickly launched an investigation into it and opened a full protection mode. In response, China had to take embargo measures one after another to contain the spread of the Covid-19 pandemic, with the consequent severe economic impact [7]. China's GDP growth rate was -6.8% in the first quarter of 2020, and only gradually turned from negative to positive in the third quarter of 2020 [8]. In addition, there are no drugs available for the complete treatment of coronavirus and patients need to maintain their vital signs

with the oxygen supply of ventilators. The increasing social investment in medical devices and the development of vaccines against the neo-coronavirus have led the market to recognize the significant value of pharmaceutical companies.

Griffin tested the Fama-French model using data from four major industrial countries and found that the international version of the model with a high degree of market integration was not as strong as the national version of the Fama-French model in explaining the changes in stock returns [9]. Furthermore, the pharmaceutical industry has policy support to continuously create new development points in research and development, and people need to have a clear investment logic and analysis of the stocks in the industry to decide whether they have investment value when considering purchasing stocks in the pharmaceutical industry [10]. Therefore, based on the Fama-French three-factor model, the paper analyzes the pharmaceutical industry in the Chinese stock market as an example to study the development of the pharmaceutical industry before and after the Covid-19 pandemic and give investors advice on stock selection.

The rest of this paper is organized as follows: Part 2 is the research design; Part 3 is discussion of the results, and Part 4 is conclusion.

2 RESEARCH DESIGN

2.1 Sample source

In this research, all A-share stocks in the pharmaceutical industry in the Chinese stock market are used as a sample, and the sample interval is from April 2017 to December 2021, the CSMAR (China Stock Market & Accounting Research Database) database and Wind database are used as the main sources of stock data for this paper.

2.2 Factor calculation

The risk-free rate of return in this paper uses the one-year Treasury rate as a proxy variable, with data from CSMAR. The rate fluctuates around 2.8% over the sample period from April 2017 to April 2022 and has a relatively flat change overall. The formula for calculating the monthly return on individual stocks is as follows:

$$R_{it} = \frac{\left(P_{it} - P_{i(t-1)}\right)}{P_{i(t-1)}} \tag{1}$$

The article chooses to use individual stock returns instead of individual monthly returns, theP_{it} and $P_{i(t-1)}$ denote the month-end closing prices of stock i in period t and period t-1, respectively. The formula for calculating the monthly market return is as follows:

$$R_{mt} = \frac{\left(M_{mt} - M_{m(t-1)} + D_{mt}\right)}{M_{m(t-1)}} \tag{2}$$

where $\mathrm{M_{mt}}$ is the monthly closing price calculated by weighting the market capitalization outstanding in period t. $\mathrm{M_{m(t-1)}}$ then is the weighted monthly closing price in period t - 1.D_{mt}

denotes stock dividends and dividend income in period t. The excess market return is calculated by the following formula:

$$R_{mf} = R_m - R_f \tag{3}$$

where the R_m is the average monthly stock return, and R_f is the risk-free rate.

2.3 Research Methodology

In this paper, stocks are grouped according to their market capitalization ME size according to the method used by Fama and French in their empirical study to construct risk factors for the three-factor model, where market capitalization less than 50% is defined as group S and market capitalization greater than 50% is defined as group B. Similarly, stocks are divided into three groups according to book-to-market ratio BE/ME size: the highest 30% of book-to-market ratio is group H, the middle 40% is group M, and the remaining lowest 30% is group L. The annual stock data are sorted by market capitalization from large to small and divided into two groups: large companies and small companies; also, the book-to-market ratio is sorted from high to low and divided into three groups: high, medium, and low. Where BE is the book value of all A-share market stocks at the end of the year (t-1) and ME is the market value of all A-share market stocks at the end of December of the year (t-1).

At this point, six portfolios can be formed, and the risk factor can be obtained by using the weighted monthly returns of the six portfolios:

$$\mathrm{SMB} = \frac{(\mathrm{S/L} + \mathrm{S/M} + \mathrm{S/H})}{3} - \frac{(\mathrm{B/L} + \mathrm{B/M} + \mathrm{B/H})}{3} \tag{4}$$

The formula represents the difference in returns between the small and large portfolios after the size factor excludes the $\mathrm{BE/ME}$ factor.

$$\mathrm{HML} = \frac{(\mathrm{S/H} + \mathrm{B/H})}{2} - \frac{(\mathrm{S/L} + \mathrm{B/L})}{2} \tag{5}$$

The formula represents the return difference between the high book-to-market ratio and low book-to-market ratio portfolios after excluding the Size factor.

The theory of the Fama-French three-factor model contains theoretical and statistical assumptions. Among them, the theoretical assumptions indicate the following conditions: first, the market has many investors, all of whom plan their portfolios of investment assets during the same security holding period. Second, investors invest only in assets traded in public financial markets and there are no securities transaction fees and taxes. Further, investors have the same expectations about the mean, variance, and covariance of security returns, and all investors have the same opinion about the evaluation of securities and the economic situation. The statistical assumption is that the model obeys the Gaussian Markov assumption.

The Fama-French three-factor model equation is expressed as follows.

$$E(R_{it}) - R_{ft} = \alpha + \beta_i \times E(R_{mt} - R_{ft}) + p_i \times E(SMB_t) + q_i \times E(HML_t) + \varepsilon_t \quad (6)$$

where R_{ft} denotes the risk-free rate at time t.R_{mt} denotes the monthly market rate of return at time t. $E(R_{mt-}R_{ft})$ denotes the market risk premium. SMB_t is the market value factor portfolio return at time t.HML_t is the portfolio return of the book-to-market ratio factor at time t.

β_i, p_i and q_i denote the coefficients affecting the market risk premium factor, the coefficients affecting the size factor, and the coefficients affecting the book-to-market ratio factor, respectively.

2.4 Descriptive statistical analysis

Table 1 shows the results of descriptive statistics. It can be found that the average value of the six groups of data for the pharmaceutical industry in the last five years is less than 0, but all of them are greater than -0.15. Within the full interval of six groups, theB/L The mean of the six groups is larger than the other five groups, which indicates that the profitability of pharmaceutical companies with large market capitalization and the low book-to-market ratio is relatively better in these five years, and companies with low book-to-market ratio are less likely to fall into financial crisis; meanwhile, it can be found that the standard deviation of the six groups is relatively larger than that of the other five groups.B/L The standard deviation of the group is also relatively larger, indicating that the investment risk is still relatively high.

Table 1 Summary Statistics, Statistical results for the whole interval

Combination	BH	BM	BL	SH	SM	SL
Average value	-0.0855	-0.0705	-0.0542	-0.0903	-0.0854	-0.0748
Standard deviation	0.07832	0.08228	0.09250	0.07988	0.07983	0.08893
Minimum value	-0.2583	-0.2189	-0.2383	-0.2126	-0.2137	-0.2325
Maximum value	0.11588	0.09559	0.16266	0.1490	0.08863	0.18630

The data before the Covid-19 pandemic indicate thatB/L the group mean is still larger relative to the other five groups, indicating that pharmaceutical companies with large market capitalization and low book-to-market ratio had relatively better profitability before the Covid-19 pandemic; howeverB/L group andS/L However, the standard deviation of the group is larger than that of the other four groups, indicating that the investment risk of companies with low book-to-market ratios before the Covid-19 pandemic is relatively higher.

Table 2 Summary statistics, Statistical results before Covid-19

Combination	BH	BM	BL	SH	SM	SL
Average value	-0.0597	-0.0466	-0.0264	-0.0677	-0.0702	-0.0541
Standard deviation	0.08274	0.08435	0.0930	0.08317	0.07987	0.09019
Minimum value	-0.2583	-0.2189	-0.2131	-0.2116	-0.2137	-0.2092
Maximum value	0.11588	0.09559	0.16266	0.1490	0.08863	0.18630

After the Covid-19 pandemic, large-cap, low book-to-market ratio firms still develop relatively well; however, at this timeB/H The standard deviation of the group is smaller than that of the

other five groups, indicating that the investment risk of large-cap high-book-to-market ratio firms has decreased after the Covid-19 pandemic, and they may be able to attract more capital in the future.

Table 3 Summary Statistics, Statistical results after Covid-19

Combination	BH	BM	BL	SH	SM	SL
Average value	-0.1209	-0.1034	-0.0924	-0.1213	-0.1064	-0.1033
Standard deviation	0.05614	0.06811	0.07858	0.06463	0.07648	0.08048
Minimum value	-0.1912	-0.2175	-0.2383	-0.2126	-0.2052	-0.2325
Maximum value	0.05480	0.06952	0.05974	-0.0039	0.05130	0.10379

3 EMPIRICAL RESULTS

3.1 ADF-test

To ensure the validity of the test results when regression analysis is performed on the data, this section performs ADF tests on the monthly returns of the six portfolios BH, BM, BL, SH, SM, and SL, and the test results are shown in Table 4.

Table 4 ADF test results

Combination	BH	BM	BL	SH	SM	SL	Market Monthly Yield
t-value	-6.8879	-5.9492	-7.1053	-6.6583	-6.8087	-5.3950	-6.8222
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000

As can be seen in Table 4, the absolute values of the six combined t-values are significantly greater than the 5% critical value of -2.933, the p-values are all less than 0.05, and the regression analysis can be performed by the ADF smoothness test.

3.2 Regression analysis

The Fama-French three-factor model is developed in this research by regressing the monthly returns of six pharmaceutical industry stock portfolios. Table 5 shows the results of the whole sample regression.

The corrected R^2 for all six groups ranged from 0.71 to 0.85, and since the closer the corrected R^2 is to 1, the better the fit is, and the better the model fits the sample data overall. In addition, all of the F-test p-values are less than 0.05, implying that the model has explanatory power for healthcare stocks by passing the F-test at the 5% level of significance.

First, the regression coefficients of the market factors are analyzed, and the p-values of the regression coefficients of the market factors for all six groups are zero, which indicates that the market factors have a significant effect on the excess return at the 5% level of significance. In addition, the regression coefficients of all six portfolios are greater than 0. Then, the excess return of the dependent variable portfolio is positively correlated with the independent variable market

excess return, among which, the regression coefficients of five portfolios, BH, BM, BL, SH, and SL, are greater than 1. Therefore, for these five portfolios, the fluctuations of their excess returns are greater than the fluctuations of the market excess returns. The coefficient of the SM group, on the other hand, is less than 1, indicating that the volatility of the market excess return is greater than its excess return for low or medium book-to-market ratio stocks.

The regression coefficients of the size factor are then analyzed, in which the regression coefficients of the small-cap stocks are all positive and the p-values are all 0. Therefore, there is a significant positive correlation between the size factor and the excess return of small-cap stocks at the 5% level of significance, while there is no significant correlation for stocks with large and medium book-to-market ratios, and large and low book-to-market ratios, indicating that the size factor has a significant effect on the BM, and BL portfolio excess return is less influential. In addition, if the coefficient of the BH portfolio is greater than zero, then the excess return of stocks with large scale and the high book-to-market ratio is positively related to the size factor.

For the book-to-market ratio factor, only the BL and SL portfolios pass the t-test, so the book-to-market ratio factor only affects stocks with low book-to-market ratios, and the regression coefficient is less than 0. Therefore, as the book-to-market ratio increases, the return of the portfolio decreases. In addition, the absolute value of the coefficient of the SL portfolio is smaller than that of the BL portfolio, indicating that the market share cannibalization effect exists in the book-to-market ratio effect.

Finally, analyzing the constant term, all portfolios fail the t-test, indicating that for all portfolios, there are factors other than these three factors that have a greater impact on the return.

Table 5 Regression results, full sample

Combination	Intercept	Coefficient			F-value	R-sq
		MKT	SMB	HML		
BH	-0.0037 p=0.6331	1.0406 p=0	0.3580 p=0.0194	0.0727 p=0.6062	78.7494	0.8064
BM	0.0078 p=0.3471	1.0849 p=0	0.2887 p=0.0683	-0.1859 p=0.2104	79.7881	0.8085
BL	-0.0070 p=0.4796	1.0023 p=0	-0.2105 p=0.2648	-0.9958 p=0	67.3111	0.7803
SH	-0.0026 p=0.7522	1.0385 p=0	0.8650 p=0	0.0448 p=0.7658	70.4100	0.7881
SM	-0.0056 p=0.5619	0.9641 p=0	1.1116 p=0	-0.2052 p=0.2420	47.9293	0.7154
SL	0.0037 p=0.6364	1.1031 p=0	1.4176 p=0	-0.8937 p=0	105.4416	0.8484

In this paper, the entire study interval was divided into two subintervals, before and after the outbreak of the Covid-19 pandemic, using January 1, 2020, as the time point, and the regression results are shown in Tables 6 and 7.

The data before and after the Covid-19 pandemic passed the F-test, but the goodness-of-fit differed significantly. The corrected R^2 before the Covid-19 pandemic ranged from 0.83 to 0.93, while the corrected R-sq decreased significantly in all groups after the Covid-19 pandemic, and the explanatory power of the three-factor model was weaker than before the Covid-19 pandemic,

in which the BH group decreased from 0.8384 to 0.5295, the BM group decreased from 0.9251 to 0.5029, the BL group decreased from 0.8407 to 0.5538, the SH group decreased from 0.8680 to 0.5022, SM group from 0.8524 to 0.4387, and SL group from 0.8618 to 0.7926.

Comparing the coefficients of the market factors, we discovered that the effects of the market factors on the excess returns before and after the Covid-19 pandemic are significant, and the coefficients of the market factors are all close to 1, demonstrating that market returns have a stronger effect on portfolio excess returns, but the coefficients before the Covid-19 pandemic are all greater than 1. After the Covid-19 pandemic, only the coefficients of the BM and SL portfolios are greater than 1. Therefore, the excess returns of the portfolios before the Covid-19 pandemic are more volatile than the market excess returns. The opposite is true for the post- Covid-19 pandemic BH, BL, SH, and SM portfolios.

Comparing the size factors again, the size factors of small-cap stocks before and after the Covid-19 pandemic pass the t-test with positive coefficients, while the coefficients of all three groups of small-cap stocks after the Covid-19 pandemic are greater than those before the Covid-19 pandemic, respectively, indicating that the impact of the size factors on the excess returns of small-cap stocks after the Covid-19 pandemic is elevated compared to that before the Covid-19 pandemic. In addition, all three groups of large-cap stocks before and after the Covid-19 pandemic fail the t-test, indicating that the size factor does not have a significant effect on large-cap stocks in both subintervals.

Comparing the book-to-market ratio factors, it can be found that only the BL and SL groups pass the t-test with negative coefficients, regardless of before and after the Covid-19 pandemic, while the absolute values of the coefficients of the two groups after the Covid-19 pandemic are greater than those before the Covid-19 pandemic, so the impact of the book-to-market ratio factor on the excess return of the portfolio has increased after the Covid-19 pandemic and they are negatively correlated.

Table 6 Regression results, before Covid-19 pandemic outbreak

Combination	Intercept	Coefficient			F-value	R
		MKT	SMB	HML		
BH	-0.0035 p=0.7153	1.0504 p=0	0.2621 p=0.2443	0.1668 p=0.3851	56.3280	0.8384
BM	0.0022 p=0.7411	1.0925 p=0	-0.0158 p=0.9185	-0.0099 p=0.9406	132.7495	0.9251
BL	0.0033 p=0.7610	1.0697 p=0	-0.0241 p=0.9226	-0.8210 p=0.0005	57.2887	0.8407
SH	0.0044 p=0.6161	1.0812 p=0	0.9074 p=0	0.2566 p=0.1460	71.1158	0.8680
SM	-0.0042 p=0.6408	1.0172 p=0	1.0880 p=0	-0.0454 p=0.7966	62.5786	0.8524
SL	0.0002 p=0.9846	1.0873 p=0	1.1549 p=0	-0.7796 p=0	67.5279	0.8618

Table 7 Regression results, after Covid-19 pandemic outbreak

Combination	Intercept	Coefficient			F-value	R-sq
		MKT	SMB	HML		
BH	-0.0106	0.9968	0.4793	-0.0646	9.6272	0.5295
	p=0.6659	p=0	p=0.0544	p=0.7871		
BM	0.0175	1.1691	0.5709	-0.4510	8.7561	0.5029
	p=0.5676	p=0	p=0.0651	p=0.1413		
BL	-0.0316	0.8072	-0.2709	-1.1341	10.5154	0.5538
	p=0.3481	p=0.0074	p=0.4067	p=0.0021		
SH	-0.0210	0.9118	0.9358	-0.1819	8.7352	0.5022
	p=0.4710	p=0.0009	p=0.0030	p=0.5226		
SM	-0.0037	0.9598	1.1575	-0.3554	6.9923	0.4387
	p=0.9184	p=0.0040	p=0.0034	p=0.3237		
SL	0.0000	1.1014	1.6860	-1.1124	30.3076	0.7926
	p=0.9990	p=0	p=0	p=0		

4 CONCLUSION

After the above analysis, this paper draws the following conclusions: (1) From the data of the past five years, the three-factor model has a better explanatory power for the stock returns of the pharmaceutical industry, but the explanatory power after the Covid-19 pandemic outbreak is not as good as before the Covid-19 pandemic outbreak. The reason is that many companies were hit more severely under the impact of the Covid-19 pandemic and various financial indicators declined, while medical stocks bucked the trend and rose rapidly. The uncertainty of medical stock returns after the Covid-19 pandemic increased due to various reasons such as the instability of investor sentiment and the intricacies of the market environment. (2) The market factor has the most significant impact on excess returns. Regardless of before and after the Covid-19 pandemic, the trend of the medical industry sector and the general stock market trend are positively correlated, so investors should note that when the general A-share market trend is upward, the greater the possibility of investing in medical stocks to obtain higher excess returns. (3) The size factor has a significant impact on small-cap stocks, and the degree of impact has increased after the Covid-19 pandemic. Investing in small-cap stocks is more likely to yield high returns, which may be due to the fact that small-cap stocks have a larger upside and downside, and are easily sought by investors, and small-cap companies have more growth potential. (4) The impact of the book-to-market ratio factor is not stable, and only stocks with high book-to-market ratios have a significant impact before and after the Covid-19 pandemic, and the impact is more significant after the Covid-19 pandemic, as the two have a negative correlation, investors should carefully choose to invest in stocks with high book-to-market ratios in the pharmaceutical sector. (5) Despite the increased demand for masks, protective clothing, and related medical devices such as nucleic acid testing, the general market trend is relatively weak and investors are susceptible to hype and stock price volatility, but as the hype disappears, stock prices gradually

level off, so the impact of the Covid-19 pandemic on the returns of stocks in the pharmaceutical sector is short-lived.

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