



Research on the Application of Fama-French Five-Factor Model in American Stock Market Before and During the COVID-19 Pandemic

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Abstract. This paper attempts to apply the Fama-French Five-Factor model to conduct a statistical study on the US stock market under the COVID-19 pandemic, evaluating the changes in the American stock market before and during the pandemic, in order to fully evaluate the applicability of this model. The research used data of Fama-French five research factors from 49 industries collected from the Kenneth R. French-Data Library during the period from May 1, 2019 to December 31, 2020, and all the statistic processing work are conducted with functions. In this study, data have been divided into two groups according to time, regarding May 1, 2019 to February 28, 2020 as the pre-pandemic stage of the study and March 1, 2020 to December 31, 2020 as the post-pandemic stage of the study. After multiple linear regression, the coefficients of the five factors of the 49 industries before and during the pandemic were obtained, and the excess returns(gain/loss), the significance changes and positive and negative changes of the five factors were further counted. According to the results, this study assessed the extent to which each factor was affected by the pandemic and collected a large amount of data to explain the anomalous industries. In addition, industries with significance changes or positive and negative changes of five factors were also be qualitatively analyzed. Meanwhile, this study compared the Mean Adjusted R-Square of the model before and during the pandemic to compare the fitting degree. In this research, it can be concluded that the Fama-French Five-Factor model has a better fitting degree for the American stock market during than before the pandemic. It's reasonable to apply this model in US stock market to find anomalies, as well as to determine the factors that need to be considered when investing in various industries, so as to decide the investment style that needs to be adopted during the pandemic.

Keywords: COVID-19 · Fama-French Five-Factor model · American stock market

1 Introduction

The outbreak of COVID-19 pandemic has made a big impact on most industries in the stock market, resulting into a reshuffle. Based on the analysis of McKinsey & Company, the reports collected from the official website of Nasdaq, and also some individual

researchers, we can have an overall look of the American stock market under COVID-19 pandemic.

In McKinsey & Company's report [1], the researchers analyzed the weighted average shareholder returns by industry since February 19, 2020, which date which noted the peak of the American stock market before the outbreak of the COVID-19 pandemic, which stimulated a dramatic decline in share prices. By gathering the data of 5,000 the world's biggest companies to their respective sectors, the researchers have examined the average shareholder returns of those mentioned sectors over 2020. At the beginning of 2020, the early stage of the pandemic, all areas showed a downward trend. While nearly half the sectors had, in the middle of the year, completely bounced back. Late October, the information of coming vaccines brought the growth of all sectors, which is considered as the widest increase over recent history.

The report from Nasdaq [2] claimed that the pandemic relief would have an impact on the American stock market. The release of new money might lead to inflation and the increase of interest rates, making the theories based on Zero-Interest Rate Policy and Modern Monetary Theory invalid. The report indicated that the stock market would at least have a 50% decrease and a high double digit's inflation.

Based on the research of British National Bureau of Economic Research [3], by having an examination on the jumps of 1,143 stock market collected in the past 120 years, they concluded that COVID-19 pandemic caused an unprecedented fluctuation to the American stock market.

The application of the Fama-French Factor models to conduct research on the US stock market during the COVID-19 pandemic is not a precedent. Scholars from various countries have used this model to study the stock market with different focuses from the macro level of the entire industry and the micro level of individual industries. Some of them also provide valuable discussion on the factors the model can apply.

Citing macro study in this field, Li and Duan (2021) [4] has conducted a macro-study on the stock markets of multiple industries in the United States, and positively affirmed the Fama-French Five-Factor models' applicability during the pandemic period. In their research they applied the Fama-French Three-Factor and Five-Factor models on thirty American industry portfolios, and the result is that the COVID-19 pandemic brought significant impact on both the market and the Fama-French models. In the model, the HML and CMA factors showed great changes, suggesting that the market turned to become less complicated over the pandemic, and in this case the pandemic make the environment suit for the Fama-French Five-Factor model. Although Li and Duan hold a positive view on the application of such model, other researchers have a negative attitude. Dominik and Wang (2020) [5] evaluated Fama-French models' performance on American stock markets by studying the R-Square of the models and later conclude that Dotcom bubble statistically significantly influenced the model's R-Square. Furthermore, they concluded that in the Gaussian Mixture Model all factors are insignificant.

In addition to the overall macro research, some researchers have conducted smaller-level research on specific industries in the US stock market, for example, pharmaceutical industries that is more easily affected by the pandemic. Xia and Hu (2020) [6] selected 223 pharmaceutical stocks as research samples from November, 2019 to June, 2020. In order to how investors' attention on the pandemic influence the pharmaceutical stock

market, they applied Fama-French Three-factor model and panel regression analysis. Investors' growing concern on the medical stock market could be described with return rate, trading volume and amplitude, which COVID-19 had a significant positive impact on during the same period, showing that the pharmaceutical sector was influenced by the pandemic most significantly.

Although good analysis results can be obtained based on existing analysis models, some researchers have focused on adjusting and improving the existing Three-factor model and Five-factor model when exploring American stock market under the COVID-19 pandemic, including supplementing important Information, the introduction of new factors and the evaluation of the sensitivity of different industries to this factor in order to obtain a more accurate analysis and provide other researchers with a more novel perspective. Violeta Díaz et al. (2020) [7] investigated the ESG ratings (Environmental, Social and Governance) to explain different industry returns during the COVID-19 pandemic. They built a ESG factor, which could explain industry returns in addition to the Fama-French factors. They concluded that ESG had the ability to demonstrate industry portfolios' returns in the pandemic, and the environmental and social pillars of the ESG were the vital motives of the observed patterns, while the influence of ESG and its pillars varied among industries. Hee Soo Lee (2020) [8] studied the original impact of COVID-19 sentiment on American stock market with big data. By using the DNSI (Daily News Sentiment Index) and Google Trends data on coronavirus related searches, she investigated the correlation between 11 select sector indices of the American stock market over the period from 21st of January 2020 to 20th of May 2020 and COVID-19 sentiment. This study examined if DNSI's changes predicted American industry returns in a different way by calculating the time series regression model with excess returns of industry, which were obtained from the Fama-French Three-Factor model, as the dependent variable. The empirical results revealed the apparently different effects of the COVID-19 sentiment across various industries.

The above-mentioned studies have all explored the impact of the pandemic on the economy, but these results did not conduct a comprehensive overall study of the US stock market, and some of the results did not provide a very detailed explanation of the data. Therefore, this paper is aimed to fill the gaps in current research and improve the above shortcomings.

2 Method

In 1964, William Sharpe proposed Capital asset pricing model (CAPM) [9]. However, the capital asset pricing model had its limitation, which put its pricing accuracy into question. Many studies' results show that asset mispricing resulted in great damage to the market of economics, which was likely to cause the financial crisis to escalate and lead to stock market crashes.

In 1998, Frankel and Lee [10] discovered that in the portfolio built by the ratio of market value to stock price, stocks with higher cash flow expectations held a higher average return rate, but the Fama-French Three-Factor model could not capture this phenomenon. Subsequently, it is proved by Novy Marx (2013) [11] that the existence of the close correlation between average return on investment and expected profitability, and

they also found that it is impossible of the Fama-French Three-Factor model to explain the changes between investment-related average return and profitability. In order to compensate for these two shortcomings, profitability and investment factors was added to the Three-Factor model in order to construct a new Fama-French Five-Factor model:

$$R_{it} - R_{ft} = \alpha_{it} + \beta_1(R_{Mt} - R_{ft}) + S_1SMB_t + h_1HML_t + r_1RMW_t + c_1CMA_t + \epsilon_{it} \quad (1)[12]$$

3 Results and Discussion

This article, based on the theory of the Fama-French Five-Factor model, collected data of 49 industries' stocks from the Kenneth R. French-Data Library [13] and dividing the data into two stages according to time and did multiple linear regression respectively. The pre-pandemic stage was from May 1, 2019 to February 28, 2020 and the post-pandemic stage was from March 1, 2020 to December 31, 2020. In the research, several definitions and judgment standards were made as follows:

1. By calculating the mean of Adjusted R-Square of the multiple linear regression of the two stages, the fitting degree of the model before and during the pandemic is obtained, so as to discuss the applicability of the model.
2. When Alpha significantly differs from 0, it means that unexplainable excess gain/loss has occurred. By comparing the Alpha before and during the pandemic, it can find out which industries had unexplained excess returns before and during the pandemic, that are, anomalies.
3. If one of the five factors of a certain industry, namely the coefficients of MKT, SMB, HML, RMW and CMA, has changed from significant to nonsignificant or from nonsignificant to significant before and during the pandemic, then a definition is made that the factor has a significance change. Through observe the statistics, it is examined that which factors have the most frequent significance changes in 49 industries, so as to analyze the impact of the pandemic on that factor. At the same time, it is also meaningful to find out which industry have experienced the significance changes of factors and discuss the reasons.
4. Finally, the definition of positive and negative changes is for a factor that is significant in a certain industry before and during the pandemic, its coefficient has changed from positive to negative or from negative to positive. By checking whether the factor coefficients that are significant in a certain industry before and during the pandemic had positive and negative changes, recommendations on whether to change the investment style in the industry can be offered.

The mean Adjusted R-Square of the Five-Factor model before and after pandemic, the number of anomalies before and after pandemic, the significance changes of five factors and the name of industries with such a significance change, as well as the number of positive and negative change of five factors' coefficients are all recorded in forms of chart and tables.

3.1 Comparative Analysis of Average Adjusted R-Square Before and During the Pandemic

As it is shown in the Figure 1, the Adjusted R-Square is 0.2817 before the pandemic and 0.5251 during the pandemic, indicating that the model fitted better during the pandemic. The poor fitting degree before the pandemic indicates, to a certain extent, that the US stock market before the pandemic is more complicated. The existing five-factor model can't explain the situation well and deserves the attention of investment analysts. One explanation for this phenomenon is that the Fama-French Five-Factor model was proposed in 2015. From 2015 to 2020, the market has experienced complex changes. As the investment environment became more complex, the model's fitting degree should get worse. However, the impact of the pandemic on the economic and social order has made the environment simpler, causing the model to fit the current market better. In the following article, cases such as the American medical equipment industry will be cited to empirically illustrate the problem (Table 1).

Table 1. Mean Adjusted R^2 of the Five-Factor model before and during pandemic.

Stage	Mean Adjusted R^2 of the 5-factor model
Before pandemic	0.2817
During pandemic	0.5251

3.2 T-Value Analysis

Interception Anomaly. By looking at whether the alpha of each industry is significantly different from 0, the existence of an unexplainable excess gain/loss can be ensured, which is called as anomaly. The specific statistics are shown in the Table 2.

Table 2. The number of anomalies before and during pandemic.

Stage	Value	Percentage
Before pandemic	Norm 47	95.92%
	Anomaly 2	4.08%
During pandemic	Norm 40	81.63%
	Anomaly 9	18.37%

By comparing the number of anomalies before and during the pandemic, it is justified that the occurrence of the pandemic has increased the unexplainable excess gain/loss, which is beyond the scope of explanation that can be covered by the existing Five-Factor model.

Before the pandemic, anomalies appeared in coal and oil industries, both of which are energy industries. In order to control the pandemic, restrictions on social and economic activities have been adopted. This has led to a sharp reduction in energy demand. In addition to the fierce competition and continuous squeezing of renewable energy in recent years, the traditional energy industry in the United States has entered a cold winter period.

The anomalies during the pandemic mainly appeared in the electronic information industry, including software, chips, lab equipment. The more obvious reflection is that the Nasdaq technology stocks have soared during the pandemic. As of July 9, 2020, technology stocks led the broader market, with Apple closing 2.3% higher, setting a record high in intraday and closing history. Tech giants such as Microsoft (249.68, 0.37, 0.15%) and Amazon (3223.07, -7.04, -0.22%)¹ also hit record closing highs.

In addition, the industries that have seen anomalies during the pandemic include autos, electric equipment, rubber, chemistry, household bank and toys, all showing high growth.

The online video conferencing service provider Zoom can be taken as an example to empirically illustrate the excess gain of the information technology industry. In the global COVID-19 pandemic in 2020, the business of Internet companies ushered in a peak of hot growth, and the online video conference service provider Zoom founded by Yuan Zheng soared, and its market value rose to USD 129 billion [14]. The product provided by Zoom is extremely simple. It is a set of video communication platform that allows users in different regions to communicate with online audio and video in real time. Affected by the pandemic, the scenes used by Zoom began to diversify, including office meetings, online courses, and even family gatherings. Compared with Google, Facebook, Microsoft, Alibaba and other companies that have launched similar products, Zoom's advantage is that it can allow more people to be online at the same time, that is, it can call reserved servers and bandwidth to maintain user experience during peak usage periods. In the end of December 2019, the highest number of Zoom's users in a single day is 10 million, including free and paid users. By March 2020, Zoom had set a record of over 200 million users a day.

The data shows that the skyrocketing of technology stocks is mainly due to the fact that related products have greatly facilitated the lives of the public in the context of the pandemic, and have played an important role in business, education, social networking and other fields. There are excess gain/loss that are difficult to explain by the model.

Significance Change of Factors. The number of industries whose significant rate have been changed and the names of specific industries are shown in the Table 3 and 4.

In general, before and during the pandemic, the value factor HML was most affected by the pandemic. The factor has significant changes in 22 industries, from significant to insignificant in 12 industries. A reasonable explanation is that the HML factor is mainly a criterion for distinguishing value stocks and growth stocks. The biggest impact of the pandemic is that people's investment methods have turned conservative. Investors tend to choose value stocks with stable profits. While grow stock rose significantly before the pandemic, it may fall more severely during the pandemic.

¹ The data in this paragraph were collected from Nasdaq official website.

The CMA, RMW, and SMB factors all changed by more than 20% (more than 10 industries in 49 industries), and the significant changes were relatively significantly affected by the pandemic. The smallest change is the market factor MKT, with only a 4% change. The two industries, rubber and coal, in which market factors have changed have both changed from insignificant to significant, indicating that the occurrence of the pandemic has made the market’s impact on these two industries greater.

In addition, the significance of the SMB, RMW and CMA factors of the medical equipment industry have changed before and during the pandemic, and all from significant to nonsignificant. This means that the scale, profitability and investment of the medical equipment industry have become unimportant under the pandemic. In fact, the arrival of the pandemic has caused stocks in the medical device industry to skyrocket, and many vaccine manufacturers and medical equipment and supplies suppliers in the American stock market have been smashed.

Table 3. The significance changes of five factors.

Factor	Number of change			Change rate in 49 industries	
	Overall	Two change modes ^a			Percentage in total change
Mkt-Rf	2	+–	0	0	4.08%
		–+	2	100%	
SMB	10	+–	6	60%	20.41%
		–+	4	40%	
HML	22	+–	12	55%	44.90%
		–+	10	45%	
RMW	15	+–	7	47%	20.61%
		–+	8	53%	
CMA	16	+–	11	69%	32.65%
		–+	5	31%	

^aThere are two change modes, which is from significant to nonsignificant(+–)and from nonsignificant to significant(–+).

As of January 28, 2020, in the case of a sharp drop in American stocks, medical device stocks and pharmaceutical stocks have risen staggeringly, from Miragen Therapeutics (NASDAQ: MGEN), a large-scale biopharmaceutical company with a stock price of about \$1, to a stock price of about \$15. NanoViricides (NASDAQ: NNVC), a small-scale nano-biopharmaceutical company, has all achieved an increase of more than 200% since January 17, 2020. Obviously, the pandemic has made medical equipment a necessary demand, made the function of the product a hard currency, and successfully weakened the role of other factors. Under this effect, the investment environment of medical equipment has become simpler. As long as it is related to the COVID-19 virus vaccine research, the

Table 4. The industries with a significance change of five factors (The definition of the abbreviation names of shares presented here can be found on the website shown in reference [13].)

Factor	Industries	
	From significant to nonsignificant	From nonsignificant to significant
Mkt-Rf	–	Rubber, Coal
SMB	Soda, Toys, MedEq, Drugs, Guns, Golds	Txtls, Mines, Util, Other
HML	Hshld, Chems, Ships, Mines, Coal, Util, Telcm, Hardw, Chips, LabEq, Whlsl, Fin	Meals, Boxes, Softw, PerSv, Aero, Txtls, Drugs, Books, Fun, Books
RMW	Beer, Smoke, Clths, Hlth, MedEq, Autos, Other	Soda, Toys, Books, Hshld, FabPr, Guns, Chips, LabEq
CMA	Toys, Hlth, MedEq, Chems, Mach, FabPr, Gold, Util, Softw, Chips, LabEq	Fun, ElcEq, Autos, Rtail, Meals

stocks of medical equipment and pharmaceutical companies have achieved substantial growth.

Positive and Negative Changes: Style Shift. The statistics on the positive and negative changes of the coefficients of the five factors before and during the pandemic are shown in Table 5.

Table 5. The positive and negative change of five factors’ coefficients

Factor	Number of change		Change rate
	Overall	Positive to negative (+–)	Overall
HML	1	+–	2.04%

From the result, the positive and negative of MKT, SMB, RMW and CMA have not changed, which means that the investment style they represent has not changed.

The only change is that the value factor, HML, of the toy industry has changed from positive to negative (Toys), indicating that in the toy field, investors before the pandemic are suitable for investing in growth-oriented tickets, while investors during the pandemic should choose stocks that can make stable profits, which is a special case in the 49 industries.

This change is mainly due to the impact of the pandemic on the supply chain of the toy industry, causing many toy manufacturers to reduce their shipments while closing offline stores, the main sales channel. For example, a listed American trend toy company Funko [FNKO.US], achieving 2020 sales of USD 650 million, an annual decrease of 18% [15]; 2020 net profit of USD 9.76 million, an annual decrease of 65%; 2020 net profit attributable to the parent company of USD 3.96 million, an annual decrease of

66%. On February 6, 2020, Funko's share price opened low and went down, from USD 15.07 the previous day to USD 9.29 in one day, a single day drop of 38%. For companies that are still in the growth stage or have insufficient e-commerce sales channels, the negative impact of the pandemic is enough to bankrupt the company. Funko has helped the company tide over the difficulties by increasing investment in e-commerce sales channels and reducing publicity and operation expenditures by reducing the cost of expenditure by 6.5%, achieved a 309.3% net profit growth in the fourth quarter of 2020. It was successful. It made up for the annual growth rate of -18.2% , -48.7% , and -14.4% in the first three quarters. Therefore, it is more practical to invest in stocks that have strong anti-risk ability, flexible capital flow, and stable profitability during the pandemic.

In general, although the pandemic has caused many companies in the US toy industry to close down, such as R Us, etc., the entire toy industry has seen a turnaround during the pandemic. According to the news released by the official WeChat account of the China Toys and Baby Products Association, the retail sales of toys in the United States will be US\$25.1 billion in 2020, an annual increase of 16%. According to relevant data released by the US market research firm NPD Group on January 25, the increase in US toy retail sales in 2020 is mainly related to the COVID-19 pandemic and the continuous changes in public consumption habits. Extensive social isolation and school closures have prompted families' disposable income to shift from other types of entertainment activities to toys. Therefore, it is a wise choice to invest in toy companies that can make stable profits.

4 Conclusion

In this paper, Fama-French Five-Factor model was adopted to evaluate the influence of COVID-19 on the American stock market. It's clear that based on Fama-French Five-Factor model, it is possible to draw some conclusions to justify that COVID-19 pandemic did make a great impact on the American stock market in several aspects. With presenting the anomalies in the investment field as well as indicating the changes of 5 factors (market, scale, value, profitability and investment) in different industries under the influence of the pandemic, this model helps investors to gain both a macro and micro understanding of the stock market, offering investors some important references. In a conclusion, the Fama-French Five-Factor model can provide investors with an effective perspective of investment analysis and help determine the investing style.

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