Analysis of U.S. industries based on Fama-French five-factor model under COVID-19

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Abstract. At the end of 2019, COVID-19 swept the world, and the United States was also hit hard. The epidemic is not only a public health crisis, but also an economic crisis. Human beings' lifestyles have undergone tremendous changes, such as reducing dine-in meals and suspending travel plans. Meanwhile, service industry that relies on interactions between customers and suppliers has been hit hard due to controlling of social distancing. This paper intends to explore the effectiveness of the Fama-French five-factor model in various industries in the United States under COVID-19 and find the changes the epidemic has brought. This paper will perform multiple regression analysis on the daily data of the five factors and industry stock portfolios obtained from the Kenneth R French database to obtain relevant results, and further analyze the model. The results show that the fitting degree of the model to the industries has improved after the epidemic. The HML factor of the service industry and the CMA factor of the paper industry have changed from significant to insignificant, while the RMW factor of the meal industry has changed from an insignificant factor to a significant one. These results reflect changes in the explanatory power of different factors for different industries under the epidemic, which reflect the severe impacts of COVID-19 on various industries in the United States, and provide new insights to better understand the Fama-French five-factor model.

Keywords: Fama-French five-factor model; U.S. industries; COVID-19.

1. Introduction

The determination of the return for a stock portfolio remains an enduring research topic in the market. During the past few decades, researchers have already come up with several main pricing models. For example, William Sharpe et al. proposed the CAPM model, which indicates that the return of an asset is largely influenced by its risk level [1]. CAPM model has long been considered as the cornerstone of the asset pricing theory, and its formula can be mathematically described as:

$$R_a = R_f + \beta_a\left(R_m - R_f\ \right) \tag{1}$$

Here, R_a is the capital asset expected return; R_f is the risk-free rate of interest; β_a stands for sensitivity; R_m is the expected return of the market. However, the CAPM model has been challenged in many ways: Firstly, the size effect cannot be well explained by the CAPM model. Secondly, CAPM model cannot greatly explain the value effect. In order to improve the validation and explanatory power of the pricing model, researchers began to try to transfer the single-factor model to multi-factor models by adding more variables into the formula. In this way, Fama-French three-factor model comes into being by adding two more factors, the SMB and HML factors. Thus, the size effect and value effect can be well explained by this newly developed model.

The three-factor model constructed by Fama and French has good forecasting effect and explanatory power for analyzing cross-sectional stock portfolio returns, and has then been widely used as an effective pricing model [2]. However, as the society continued to develop, the applicability of the model was challenged and its explanatory power was declining. Researchers found that FF3 model cannot rightly define the intercept a in some stocks, which means the FF3 model had also become defective. Subsequently, on the basis of the three-factor model, Fama and French refined the model by adding two more factors, RMW and CMA, into the formula, and the five -factor model came into practice ever since. During the past few years, the explanatory power of Fama-French five-factor model has been greatly proved in the US [3].

Contemporarily, many scholars have borrowed this model to conduct in-depth analysis of various fields and industries in different countries thanks to the effectiveness of the FF model in practice. Martins et al. use the Brazilian stock market in the past 12 years (2000.01-2012.12) to test the validity and performance of the FF5 model. The research results show that the FF5 model, compared with the previous FF3 model, does a better job of measuring Brazilian stock market returns [4]. Even if the performance of the three factors mkt, SMB, and HML has not improved significantly, the newly added two factors RMW and CMA played a positive role in it.

Nartea et al. use the data of stock market in Hong Kong from 1982 to 2001 to test the persistence and robustness of size and value premiums for Fama-French three-factor models in explaining changes in stock returns. The findings show that the explanatory power provided by the FF3 model is much improved compared to the CAPM model, i.e., the size and value premiums are returns for risk-taking [5].

Similarly, Clive Gaunt tests the effectiveness of FF3 model using data from Australian stock market. The time period he selects is from 1981 to 2000 and the results show that the Fama-French three-factor model provides significantly improved explanatory power over the previous CAPM model. Moreover, the book to market effect does play an important role in asset pricing [6].

Cakici et al. highlight the relevance and efficacy of the FF model to regions. They test five-factor models for 23 developed stock markets, using company-level data from July 1992 to December 2014 to generate 25 scales of book-to-market value. Then three-, four-, and five-factor models are adopted to explain the returns of 25 portfolios using regional and global factors [7]. Ultimately, it is concluded that the results of the five-factor model for North American, European, and global markets are similar to those for U.S. equities. However, the addition of two factors (RMW, CMA) either adds no potency or is much weaker in Japan and Asia Pacific portfolios compared to Europe and the US. Taken together, the FF5 regional model performs better than the global model, which may mean that the global market is not yet fully integrated.

Acaravci et al. also try to test the validity of the FF5 model in BIST. The purpose of this study is to test the validity of the Fama-French five-factor model (FF5F) at BIST between July 2005 and June 2016. According to the analysis, 14 different crossover portfolios are constructed based on market size, P/E ratios, profitability and investment factors [8]. Based on the evaluation, there is no mispricing of the FF5 model. Therefore, FF5F is valid in BIST and can explain variation in excess portfolio returns.

Munawaroh et al. test the validity of the Fama-French five-factor model for stock portfolios listed in ISSI. The data is retrieving from 2013.01-2017.12 and a least-squares regression is applied to analysis on monthly stock portfolio data of 183 company stocks [9]. The results show that SML and CMA have a positive explanatory effect on ISSI's investment portfolio.

Although predecessors have conducted multi-dimensional tests on the effectiveness of the FF model from various perspectives, there is still a lack of relevant research results on the effectiveness of the FF model under the epidemic. Therefore, based on the Fama–French five-factor model, the paper will discuss the changes in factors of many industries in the United States before and after the epidemic, and systematically analyze these industries in order to further understand the model.

The rest part of the paper is organized as follows. The Sec. II will introduce the methodology used in this paper. The Sec. III will show the empirical results of the linear regression, followed by the discussion of changes in these five factors before and after the epidemic in the Sec. IV. In the end, there will be a conclusion of this paper analysis.

2. Methodology

2.1 Data

This research intends to explore the effects of applying the FF5 model to different industries. There are certain differences in the selected five industries. Among them, the meals and service industries are industries that naturally rely on strong relationships between people, while the paper making, transportation, and finance industry are not as people-to-people connected. Therefore, the impacts of the epidemic on these five industries are also very different. In this research, multiple regression analysis will be performed on the data, and the t-value, correlation coefficient, std, p-value and R^2 value will be obtained with 95% confidence interval. The relevant data comes from the Kenneth R French database, and Fama-French 5 Factors [Daily] and 30 Industry Portfolios [Daily] are selected as the data sets for analysis [10]. In order to effectively reflect the changes before and after the epidemic, we divided all data into two segments according to the time series, namely 2019.03.01-2020.02.28 before the epidemic and 2020.03.01-2020.09.31 after the epidemic.

2.2 Models

The model tested in this paper is the Fama-French five-factor model (FF5F), which was proposed by Fama and French in 2015. The model is designed to predict average returns on stocks by taking into account size, value, profitability, and investment patterns. Its specific expression is as follows:

$$R_{it} - R_f = \beta_{i1}(R_{mt} - R_f) + \beta i_2 SMB_t + \beta_{i3} HML_t + \beta_{i4} RWM_t + \beta_{i5} CMA_t + \epsilon_{it} \tag{2}$$

Here, R_f is the risk-free rate of return; R_m is the market rate of return; R_i is the return on asset i; $E(R_m) - R_f$ is the market risk premium. MKT-Rf refers to the ratio of a stochastically diversified risk market portfolio minus the return on risk-free assets. SMB is the simulated portfolio rate of return for the size factor; The specific contents of the five factors are as follows. Companies with smaller assets are riskier, so investors can earn higher returns, while companies with larger assets are less risky, so investors can only earn lower returns. In this case, the SMB calculation should be positive, as smaller companies typically have higher revenue than larger companies.

$$SMB_t = \frac{SL_t + SM_t + SH_t}{3} - \frac{BL_t + BM_t + BH_t}{3} \tag{3}$$

HML represents the premium for a business opportunity and can be calculated by subtracting the earnings of companies with a low book P/E ratio from the earnings of companies with a high book P/E ratio. Companies with high book price-to-earnings ratios perform poorly on fundamental analysis and have poor financial health. In this case, investors invest in them with both higher risk and higher returns. By contrast, stocks of companies with low book-to-earnings ratios are growth stocks and they have enough room to grow. Therefore, investors invest in it have both lower risk and lower return. Based on the above analysis, the calculated result of HML should be positive. In addition, $\beta_{HML}>0$ indicates that the industry tends to consist of companies with high book-to-earnings ratios and has limited room for growth.

$$HML_t = \frac{BH_t + SH_t}{2} - \frac{BL_t + SL_t}{2} \tag{4}$$

RMW is the profitability factor, which measures the difference between the high and low operating margins of a portfolio of stocks. This factor reflects the premium, comparing a portfolio of high profitability stocks to a portfolio of low profitability stocks. Generally, industries with relatively high profitability are higher risk.

$$RMW_t = \frac{BR_t + SR_t}{2} - \frac{BW_t + SW_t}{2}. \quad (5)$$

CMA is the investment factor, which is the difference between a conservative investment and an aggressive investment for a stock portfolio. This factor reflects the premium, comparing patterns with high and low investment ratios. Usually, companies with low investment rates are riskier. For these companies, investors demand higher rates of return.

$$CMA_t = \frac{BC_t+SC_t}{2} - \frac{BA_t+SA_t}{2} \quad (6)$$

3. Results

The results obtained are listed in the Tables. I- III. Seen from the results, we can clearly notice the differences and changes of data before and after COVID-19. From the data in the tables, it can be seen that the fitting degree of the FF5 model to the stock portfolio in the industry after the epidemic is higher than the fitting degree of the model to the industry data before the epidemic.

Tables I. Coeffiecient and T value of five industries before and after COVID-19.

Period	Industry	FIN		MEALS		PAPER		SERVS		TRANS	
	Factory	Coefficient	t Stat	Coefficient	t Stat	Coefficient	t Stat	Coefficient	t Stat	Coefficient	t Stat
Before	MKT-RF	0.807	40.839	0.738	17.247	0.908	19.236	0.936	41.013	1.041	24.475
	SMB	0.395	11.282	0.337	4.448	0.801	9.575	0.457	11.304	0.853	11.312
	HML	0.502	14.151	0.123	1.600	0.155	1.826	-0.249	-6.079	0.416	5.449
	RMW	-0.365	-6.482	0.246	2.014	0.275	2.046	-0.126	-1.945	0.598	4.937
	CMA	-0.044	-0.622	0.100	0.656	0.471	2.800	-0.273	-3.357	-0.057	-0.374
After	MKT-RF	0.909	49.598	0.971	13.772	0.859	27.068	0.931	43.789	0.885	27.146
	SMB	0.642	13.553	1.135	6.235	0.737	8.999	0.698	12.709	0.737	8.751
	HML	0.695	17.503	0.469	3.073	0.531	7.719	0.031	0.682	0.442	6.260
	RMW	-0.223	-2.699	0.915	2.882	0.100	0.701	-0.148	-1.542	0.518	3.530
	CMA	-0.186	-1.628	-1.926	-4.397	0.272	1.379	-0.654	-4.950	-0.355	-1.753

Tables II. Std and P value of five industries before and after COVID-19.

Period	Industry	FIN		MEALS		PAPER		SERVS		TRANS	
	Factory	**Std**	**Prob**	**Std**	**Prob**	**Std**	**Prob**	**Std**	**Prob**	**Std**	**Prob**
Before	**MKT-RF**	0.020	0.000	0.043	0.000	0.047	0.000	0.028	0.000	0.043	0.000
	SMB	0.035	0.000	0.076	0.000	0.084	0.000	0.040	0.000	0.075	0.000
	HML	0.035	0.000	0.077	0.111	0.085	0.069	0.041	0.000	0.076	0.000
	RMW	0.056	0.000	0.122	0.045	0.135	0.042	0.065	0.053	0.121	0.000
	CMA	0.071	0.534	0.153	0.512	0.168	0.006	0.081	0.001	0.152	0.709
After	**MKT-RF**	0.018	0.000	0.070	0.000	0.032	0.000	0.021	0.000	0.033	0.000
	SMB	0.047	0.000	0.182	0.000	0.082	0.000	0.055	0.000	0.084	0.000
	HML	0.040	0.000	0.153	0.003	0.069	0.000	0.046	0.496	0.071	0.000
	RMW	0.083	0.008	0.317	0.005	0.143	0.484	0.096	0.125	0.147	0.001
	CMA	0.114	0.106	0.438	0.000	0.197	0.170	0.132	0.000	0.203	0.082

Tables III. R square value of five industries before and after COVID-19.

Period	Industry	FIN	MEALS	PAPER	SERVS	TRANS
Before	R^2	**0.918**	**0.645**	**0.736**	**0.910**	**0.834**
After	R^2	**0.978**	**0.801**	**0.930**	**0.958**	**0.928**

4. Discussion

4.1 The coefficient of mkt_rf

According to the data in Table I, among these five industries, the MKT factor coefficients of the meal industry and the financial industry have increased after the epidemic, and the market risk premium level has risen significantly. The level of the market risk premium has decreased in transportation and paper industries compared with the overall risk of the market. Thereinto, the MKT factor beta coefficient of the meal industry increased most significantly, from 0.738 before the epidemic to 0.971 after the epidemic. In this case, after the epidemic, the MKT factor of the meal industry has stronger explanation power to the whole market. With the continuous recurrence of the epidemic in the United States and the social distancing restrictions it has brought, the American meal industry has suffered a major blow. The revenue of chain giant such as McDonald's has dropped sharply, while the small restaurant practitioners are more faced with the dilemma of closing their stores and losing their jobs. On July 29, 2020, Starbucks released its second quarter financial report. The company's revenue fell 38.1% year over year to $4.22 billion, and net income turned from a profit of $1.37 billion to a loss of $680 million. Just as the large chain restaurant groups are going through the cold winter of the industry, some small restaurants are already struggling to maintain. U.S. restaurant revenue fell by an average of 33% in the wake of the COVID-19 pandemic, while restaurant revenue in New York City fell by an average of 68%. The change in the MKT beta coefficient reflects the fatal blow to the U.S. meal industry brought about by the epidemic. In general, after the epidemic, the meal and financial industries have higher overall risk levels than the transportation, paper and service industries.

4.2 The coefficient of SMB

It can be seen from Table I that the SMB coefficients of these five industries exhibited significantly positive results both before and after the epidemic. To be specific, the SMB coefficients of the financial, meal and service industries have increased after the epidemic; on the contrary, the SMB coefficients of the paper and transportation industries have decreased. SMB is a factor that measures the difference between the returns of small-cap stocks and large-cap stocks in a diversified portfolio. The coefficient of the SMB factor decreases significantly with the increase of the market value. The small-scale market value group is all positive, and the large-scale market value group has a coefficient close to 0 or even negative. Negative beta coefficients generally appear in industries that rely on scale effects, (e.g., public service industries including electricity, water conservancy and other services) and the market value of their stocks is always large. In this type of industry, if large-cap stocks perform well, the industry's overall returns will also become higher, and small-cap portfolios may suffer. Therefore, some stock betas such as public service industries will be significantly negative. The five industries discussed in this paper are relatively small-capitalized and highly specialized industries, and their SMB beta coefficients are all positive. It is worth mentioning that in the face of 'black swan events' (e.g., the outbreak of COVID-19), industries with positive SMB beta coefficients will be more severely affected, because the social distancing between people is not conducive to the procedures of these industries [11]. Apparently, the SMB beta coefficients of industries that rely on people-to-people interactions, such as the meal industry and the service industry, have increased to a large extent, which shows that the SMB factors of these industries can better explain the market under the epidemic than before the pandemic. Nevertheless, the SMB coefficients of the paper and transportation industries, which relatively do not require human interaction, have decreased, and the factors' explanatory power to the broader market has decreased. The numerical changes in these factors reflect the severe negative impacts of the epidemic on these five industries in the United States.

4.3 The coefficient of HML

According to the regression analysis results, the HML beta coefficients of the selected five industries have all increased after the epidemic, indicating that the explanatory power of these factor has improved. The HML factor represents the premium for a business development opportunity, and it can be calculated by subtracting the earnings of companies with a low P/E ratio from the earnings of companies with a high P/E ratio. The coefficient of the HML factor shows a trend of increasing with the increase of the book-to-market ratio, and has a significant value effect. In detail, the coefficient of the HML factor of the service industry was negative before the epidemic, and became positive after the epidemic. This change shows that the interpretation of the HML factor to the broader market has improved significantly after the epidemic. The change in data also indicates that the epidemic has brought a huge blow to the service industry, reducing the number of growth stocks and limiting the development space of the industry. The damage caused by the epidemic to the US service industry is obvious. The epidemic has restrictions on people's going out. Therefore, services such as laundry, beauty salons, and electronic repairs included in the service industry are greatly restricted. The transportation industry has the least significant change in the HML factor coefficient among the five industries. It is also owing to the fact that the transportation of water and electricity resources included in the transportation industry are relatively automated, and are not greatly affected by the epidemic. The results also denote that compared with the SMB factor, the explanatory power of the HML factor has decreased, and the effect of the value effect has been weakened.

4.4 The coefficient and T value of RMW

RMW measures profitability, which is the difference between a portfolio of stocks with high and low operating margins. It's worth noting that RMW measures excess returns for companies with higher operating margins, not companies with lower margins. In general, higher profitability represents higher industry risk. The data in Tables I means that the RMW coefficient of the meal industry has the most obvious growth among the five industries, increasing from 0.246 before the epidemic to 0.915 after the epidemic; while the RMW coefficient of the paper industry has a significant decrease after the epidemic, and its T value also decreased from 2.046 to 0.701. In other words, RMW before the epidemic was an important factor for the paper industry (T is greater than 1.96), but with the outbreak of the epidemic, the factor became less important, and its explanatory power also weakened. It reflects the negative impact of the epidemic on the US paper industry, which has greatly reduced its profit margins. For example, the global epidemic has led to a decline in China's imports of fiber raw materials, resulting in an oversupply of pulp in the United States. In addition, consumers' consumption patterns have also been affected by the epidemic. From the perspective of the paper industry, this directly affects the demand for packaging. All in all, COVID-19 has made the RMW factor of the paper industry less significant.

4.5 The coefficient and T value of CMA

CMA is an investment style factor, which represents the difference between the conservative investment style and the aggressive investment style of a stock portfolio. This factor reflects the premium, comparing patterns with high and low investment ratios. Generally speaking, companies with lower investment rates are riskier. From the data shown in Tables I, it can be seen that for the CMA factor of meal industry has changed from a redundant factor before the epidemic to a significant factor after the epidemic (the absolute value of the t value is greater than 1.96), while the CMA factor of paper industry changed from a significant factor to an insignificant one. The CMA factor of the service industry was significant both before and after the epidemic, while the CMA factor of the transportation and financial industries remained insignificant. The changes in the data reflect that among these five industries, the meal industry and the paper industry are the more vulnerable and volatile industries in the context of the outbreak of the epidemic.

4.6 Limitations

Considering the repeatability and periodicity of the epidemic, this paper does not select a too long time period when selecting the time period. Instead, the time period selected is a relatively short six-month period of 2020.03-2020.09 after COVID-19. However, this action also brings certain drawbacks, which makes the R square value after COVID-19 slightly higher than the normal value, but it is also an unavoidable compromise. Besides, the amount of data from Kenneth R French Library is limited, which may also lead to some slight bias to the regression results.

5. Conclusion

In summary, this paper aims to test the validity of the Fama-French five-factor model for the financial, service, meal, paper, and transportation industries in the United States, and discuss the changes in different industry factors before and after the epidemic. According to the results, after the outbreak of the epidemic, the HML factor of the service industry and the CMA factor of the paper industry have changed from significant to insignificant, while the RMW factor of the meal industry has changed from an insignificant factor to a significant one. Based on multiple regression analysis on the data of five industries, this research deeply explores the effectiveness of the FF5 model under the epidemic. In the future, researchers can dig deeper into the validity and limitations of the FF5 model in the US stock market under COVID-19. Overall, these results offer a guideline for investors to make reasonable and correct investment decisions in the context of COVID-19.

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