The impact of the Chinese semiconductor industry based on the Fama-French five-factor Model During the COVID-19

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Abstract. The COVID-19 has had a significant impact on the global economy and actual economy. The semiconductor business has risen quickly in recent years, and the influence of COVID-19 on the semiconductor sector cannot be overlooked. As a result, based on semiconductor industry data, this research explores the applicability of the Fama-French five-factor model as well as changes in the five-factor coefficients before and after the epidemic. In particular, the data is obtained from CSMAR and the data span a four-year period, from January 2018 to December 2021. This paper first summarizes the relevant studies and literature in the past, then explains the meaning of capital asset pricing model and model equations, and uses the data of CASMR to conduct multiple regressions and obtain the coefficients of the five-factor model and T stat. Finally, the empirical results are analyzed and the corresponding conclusions are given. The results of this paper give the changes in the equations of the Fama-French five-factor model before and after the outbreak of the epidemic. According to the analysis, the comparison helps to determine the impact of the epidemic on the model and the market. These result shed light on guiding further investment and risk analysis..

Keywords: Semiconductor Industry; China Stock Market; Fama-French five-factor model; COVID-19.

1. Introduction

Semiconductor began to develop rapidly in the middle and late 20th century, and has made great progress so far. The application of semiconductor has changed our way of life. By promoting the construction of various infrastructure, it has closed the relationship between people, provided people with more ways of entertainment, and economic development. However, the outbreak has a huge impact on the semiconductor industry and must be taken very seriously.

When COVID-19 sweeps across the world, every industry is deeply involved in this disaster, in which semiconductor industry is no exception. Although the production of many chips has been fully automated, plenty of sophisticated production processes still require the participation of technicians, and the epidemic has greatly limited this activity. After the outbreak of the epidemic, plenty of employees work at home, and the demand for end products (e.g., chips) is growing rapidly, which also puts great pressure on the development of the semiconductor industry.

The capital asset pricing model (CAPM) may be used to determine stock returns by reflecting the link between expected return and market risk. The beta component alone, according to Fama and French, cannot explain market return. When the other two variables, scale factor and book value factor, were added to compensate for the CAPM's deficiency, the three-component model did a good job of describing the cross-section of stock return. Fama and French create a five-factor model by adding two mimicking components to the three-factor model to capture profit and investment return premiums. As a consequence, the Fama-French five-factor model may be used to evaluate COVID-19's impact on the semiconductor industry and identify the factors that affect the market return rate.

By choosing U.S. actively managed equities mutual funds from April 1986 to March 2006, Bello investigates the validity of the CAPM, the Fama-French (FF) three-factor model, and Carhart's extension of the FF model. In terms of prediction quality, the FF three-factor model outperforms the

CAPM, and the carhart model outperforms the FF model, but the difference between the three is not significant in terms of statistical fit [1]. Clarice and William use data from the Brazilian stock market from January 2000 to December 2012 to test the five-factor model's explanatory capacity for stock returns. In the selected Brazilian stock market dataset, the empirical results reveal that the market components SMB and HML are able to capture the majority of the variance in average returns, whereas the explanatory power of RMW and CMA is rather modest [2]. Foye tests if the new Fama-French five-factor model can better reflect stock returns in developing economies than the three-factor model by choosing 18 countries from three regions: Asia, Latin America, and Eastern Europe. The five-factor model is superior to the three-factor model of Latin America and Eastern Europe., but not in Asia [3]. Returning to the mature and developed capital markets, Chiah et al. use a large sample from 1982 to 2013 to explore the five-factor model's explanatory power in Australian equities pricing. The five-factor model offers higher explanatory power for asset pricing anomalies than other asset pricing models, according to the study, demonstrating its superiority [4]. Dirkx and Peter discuss how the Fama-French five-factor model may be applied to the German stock market. The findings indicate that the Fama-French five-factor model is no more convincing than the Fama-French three-factor model. They suggest that profitability and investment considerations do not adequately explain the return on equity assets in the German stock market, using data from 2002 to 2007 [5].

After the outbreak of the COVID-19, scholars from various countries studied the effectiveness of asset pricing models under the epidemic. Liu analyzed the applicability of the Fama-French five-factor model by selecting daily data for 49 hardware industrial portfolios from 2019.7.1 to 2020.10.30 and applying multiple linear regression. According to the analysis, the outbreak has had a negative impact on the U.S. hardware industry and that the explanatory power of CAPM is greater [6]. Horváth and Wang tested the goodness-of-fit of the Fama-French five-factor model during COVID-19 and performed a robustness test using GMM. It was found that there was a significant decrease in the goodness of fit after the outbreak of covid-19. However, in the meantime, they also illustrate that covid-19 is still ongoing, so further calculations and verification of the effect of covid-19 on the model are pending [7]. Sun used an OLS approach to examine the performance of a portfolio of 49 firms in a five-factor Fama-French model in the U.S. market before and after the outbreak. According to the empirical data, the Fama-French five-factor model has a higher R-squared value. During COVID-19, the Fama-French model enhanced its capacity to explain portfolio outcomes across all sectors. Although the Fama-French model's goodness of fit has increased, there are still certain sectors where the model cannot explain circumstances that occurred before and after the epidemic [8].

Before and after the outbreak of the epidemic, the trading activities in the capital market have undergone great changes, and the epidemic has affected all industries. In this paper, the semiconductor industry was selected as target industry to study the impact of COVID-19. Contemporarily, it has had a profound impact on the short- and long-term development of the semiconductor industry. In the short term, the epidemic has affected the resumption rate and raw material trading of the semiconductor industry. In the long run, the epidemic has affected the investment in the semiconductor industry and the attraction of global high-tech talents. When stocks in a certain sector rise, that industry's sales, earnings, and plant and equipment outlays typically climb as well. Therefore, stock price reactions should reveal how different sectors are affected [9]. Fama-French five-factor model is feasible in many industries. Therefore, this study will apply the model to detect the semiconductor industry, discuss the changes of five factors before and after the epidemic, and give reasonable investment suggestions to investors.

The rest of this paper is laid out as follows. The second section will include data selection, the CAPM model, and the Fama-French five-factor model, as well as a summary of the data's fundamental properties. The findings of the OLS regression will be analyzed and elaborated in Sec. III. In Section IV, a concise summary will be provided.

2. Methdology

2.1 Data

The data for this paper is selected from CSMAR, where the five factors as well as the equity risk premium are selected for the time period from January 4, 2018 to December 31, 2021. 132 companies were selected from the Chinese semiconductor industry and 92,337 pieces of data ($R_m - R_f$, SMB, HML, RMW, CMA and $R_i - R_f$) in the daily frequency are selected from CSAMR and applied to the Fama-French five-factor model.

2.2 Models

In 1964, a model was proposed by Sharpe, which was called the Capital Asset Pricing Model (CAPM), and Sharpe used it mainly to illustrate the relationship between expected returns and expected risk [10]. According to this model a linear equation was obtained as:

$$R_{it} - R_F = \beta_I (R_{mt} - R_F) \tag{1}$$

Where, R_{it} is expected rate of return on asset I, R_F is risk-free rate of return, β_I is beta coefficient, which is the systematic risk of asset I, and $R_{mt} - R_F$ is market risk premium. Nevertheless, the CAPM has significant limitations, as each of its assumptions is very stringent and the individual risk factors are not the only determinants of stock impact and do not explain well the differences between stock returns and the cross-section, as confirmed by a number of studies conducted by Banz [11]. Based on the CAPM model, combining the two factors SMB and HML with the market factor, Fama and French proposed a three-factor model and obtained the linear equation [12]:

$$R_{it} - R_{Ft} = a_i + b_i (R_{Mt} - R_{Ft}) + s_i SMB_t + h_i HML_t e_{it} \tag{2}$$

This model can predict stock returns more accurately than CAMP. In a paper tabulated by Novy [13], it is suggested that there is a close relationship between average return bar and profitability, but the Fama French 3factors model cannot explain the relationship between investment-related averages and profitability. Therefore, Fama and French introduce investment factor and profitability factor into the three-factor model thus constructing the FF five-factor model and presenting the linear equation [13, 14] in order to fill these two gaps:

$$\begin{gathered} R_{it} - R_{Ft} = a_i + b_i (R_{Mt} - R_{Ft}) + s_i SMB_t + h_i HML_t + \\ r_i RMW_t + c_i CMA_t + e_{it} \end{gathered} \tag{3}$$

Here, R_{Ft} is the risk-free return rate for time t, R_{Mt} is the market return rate for time t, R_{it} is the rate of return for asset i at time t; R_{it}-R_{Ft} is the market risk premium. SMB_t is the simulated portfolio yield (small minus big) of the market value (size) factor of time t, which can be obtained as:

$$SMB_t = \frac{SL_t + SM_t + SH_t}{3} - \frac{BL_t + BM_t + BH_t}{3} \tag{4}$$

HML (high minus low) simulates the portfolio yield of the book to market ratio factor at time t, its calculation formula is:

$$HML_t = \frac{BH_t + SH_t}{2} - \frac{BL_t + SL_t}{2} \tag{5}$$

The average return on robust operational profitability portfolios minus the average return on poor operating profitability portfolios is RMW (Robust Minus Weak), which can be described as:

$$RMW_t = \frac{BR_t + SR_t}{2} - \frac{BW_t + SW_t}{2} \tag{6}$$

The average return on conservative investment portfolios minus the average return on aggressive investment portfolios is known as CMA (Conservative Minus Aggressive), its calculation formula is:

$$CMA_t = \frac{BC_t + SC_t}{2} - \frac{BA_t + SA_t}{2} \tag{7}$$

2.3 Descriptive statistical analysis

Table I shows the descriptive statistics. All six variables have 92,337 pieces of data. The mean of $R_m - R_f$ is 0.000 with a standard deviation of 0.12. SMB has a standard deviation of 0.007 and a mean of 0.000. HML has a -0.0003 mean and a 0.007 standard deviation. RWM has a 0.0002 mean and a 0.006 standard deviation. CMA has a standard deviation of 0.005 and a mean value of -0.000. The mean value of $R_i - R_f$ is 0.002 with a standard deviation of 0.062. Table II lists the correlation coefficients. The correlation coefficient between $R_i - R_f$ and $R_m - R_f$ is 0.245. The correlation coefficient between $R_i - R_f$ and SMB is 0.137. Nevertheless, the correlation coefficients between $R_i - R_f$, HML, RWM, and CMA are all negative, -0.189, -0.065, and -0.051, respectively.

Table I. Descriptive Statistics.

	$R_m - R_f$	SMB	HML	RWM	CMA	$R_i - R_f$
count	92337	92337	92337	92337	92337	92337
mean	0.000	0.000	-0.000	0.000	-0.000	0.002
std	0.012	0.007	0.007	0.006	0.005	0.062
min	-0.080	-0.033	-0.023	-0.023	-0.019	-0.213
50%	0.001	0.001	-0.001	0.000	-0.000	-4.1E-05
max	0.057	0.019	0.021	0.024	0.017	7.972

Table II. Correlation coefficient of variables.

	$R_i - R_f$	$R_m - R_f$	SMB	HML	RWM	CMA
$R_i - R_f$	1.000	0.245	0.137	-0.189	-0.065	-0.051
$R_m - R_f$	0.245	1.000	0.091	-0.396	0.008	-0.250
SMB	0.137	0.091	1.000	-0.197	-0.666	0.435
HML	-0.189	-0.396	-0.197	1.000	-0.201	0.524
RWM	-0.065	0.008	-0.666	-0.201	1.000	-0.728
CMA	-0.051	-0.250	0.435	0.524	-0.728	1.000

3. Results

Through the analysis of the selected semiconductor industry related stocks, some factors no longer have reliable effectiveness after the epidemic as presented in Table. III. Among the five factors $R_m - R_f$, SMB, HML, RWM and CMA, the first four are still effective though they fluctuate in some extent, but the last one is not.

The popularity of COVID-19 has undoubtedly led to global economic shocks. It has also brought some new hidden factors in changing the traditional pricing factors. In order to eliminate these insidious factors, the author selected the data of semiconductor related stocks from 2018 to 2021 and took January 23, 2020 is the dividing point for the outbreak of the epidemic. Depending on the big data method, after processing the data of COVID-19, the correlation between the five factors in these two stages can be obtained and the changes can be clearly contrasted. It is generally believed that when the absolute value of T stat data is greater than 1.96, the correlation is significant at 5%. The greater the tangent value is, the closer the correlation is. Affected by the epidemic situation, the correlation of$R_m - R_f$, SMB and RMW has decreased, but the range is not obvious and there is still a strong correlation. Among all the factors, the only one with increasing correlation is HML, which is more closely related to the profitability of the semiconductor industry. The most special data comes from CMA, whose absolute value of T stat has been reduced from 10 to 1.9, which means that its reliability has been denied. Obviously, this means that the investment mode factor is no longer suitable for the analysis of the profit factor in the five-factor model under the influence of COVID-19, and it has an impact on the validity of the five-factor model.

The epidemic of COVID-19 is a long-term and sustained event. Based on analysis, it has been known that it has had a long-term and sustained impact on different industries. Moreover, there is still a long way to go before the end of the epidemic, which makes it possible for the semiconductor industry to change in the later stage of the epidemic and after the end of the epidemic. The relationship between epidemic changes and the industry deserves further attention.

Table III. The estimated coefficients of the five factors and their corresponding t-statistics for theperiod before and after COVID-19.

Factors	Before		After	
	Coefficient	t Stat	Coefficient	t Stat
$R_m - R_f$	0.872	48.013	1.114	38.014
SMB	0.760	12.634	0.670	10.930
HML	-0.645	-10.481	-0.970	-15.879
RWM	-0.571	-7.934	-0.710	-6.858
CMA	-0.851	-10.010	-0.259	-1.941

4. Discussion

4.1 Coefficient of RMW

RWM represents the profitability factor that captures the relative changes of stocks with the profit premium. Before the outbreak, the coefficient of RMW was -0.571, however, the RMW factor is not static. After the outbreak, RMW has remained a negative value and has slightly decreased, down to -0.710, which also shows that RMW is not an important factor for the semiconductor industry. Due to the scarcity of technology and talent, and the fact that there is still a big gap between China and other countries such as the United States in the semiconductor field, some companies were already facing failed operations before the outbreak, and after the outbreak, this has put higher demands on the financial operation capability of companies. Besides, the outbreak has also caused a major impact on the global economy, which also shows a small decrease in the RMW factor. Although the change is not significant, but it can also show that the impact of the epidemic on the profitability of the semiconductor industry is negative.

4.2 Coefficient of CMA

A coefficient over captures the relative changes of stocks with the investment premium. The coefficient of CMA before the outbreak was -0.851, however, after the outbreak, there was a significant change in CMA, increasing to -0.259, which also indicates a more optimistic attitude towards the semiconductor industry. Although precision activities such as chip packaging in the semiconductor industry require manual operations and the epidemic has limited human activity, this is only one-sided. The rapid development of the semiconductor industry requires that the process from production to sales be fully automated, which has given the semiconductor industry a significant advantage over other industries, e.g., the service industry and automobile manufacturing that require a large amount of manual manufacturing. The change in the CMA coefficient is consistent with the trend of $R_{it} - R_{\mathrm{ft}}$, which indicates that the outbreak of the new crown epidemic has also changed the investment preference of some people from other industries to the semiconductor industry. Although the overall market will report a decline, but people's enthusiasm for investment in the semiconductor industry has increased.

4.3 Coefficient of $\boldsymbol{R_m - R_f}$

The disparity between bond yield and the base interest rate is known as the risk premium, and it indicates the additional risk that investors bear when investing in non-treasury bonds. After the outbreak, the coefficient of this item increased from 0.872 to 1.114. Although the coefficient increases, the t Stat decreases. It shows that in the epidemic, although the opportunities for high investment and high return have increased, investors are unable to judge the source of risk well because they are worried about the changes and impact of the general environment. On the contrary, it leads to the conservative attitude of investors.

4.4 Coefficient of SMB

SMB refers to the market value of the stock, which is the product of the stock price and the total share capital. After the epidemic, the coefficient and correlation of market value factor decreased, the coefficient decreased from 0.760 to 0.670, and the t Stat decreased from 12.634 to 10.93. Market value can intuitively reflect the current overall situation of the industry. The change of SMB means that the stock market is declining, and the market value of COVID-19 has dropped. Although the impact on the industry is not high, the impact still exists. The semiconductor industry belongs to the field of high and new technology, and the long-term factors are not significantly different from each other, indicating that the whole industry is less affected by COVID-19.

4.5 Coefficient of HML

The book to market value ratio factor of HML is the ratio of shareholders' equity to the market value of the company. The coefficient of modification factor decreased to – 0.970 after the epidemic, and the t Stat increased by nearly half. A negative HML coefficient means that the total liabilities of relevant enterprises are greater than the total assets, and the net assets per share are negative. The decrease of the coefficient means that the debt ratio of relevant enterprises increases. In modern management, high debt ratio does not mean business failure, but the increase of debt ratio can reflect the problems of the company's operation. During the period of COVID-19, the more serious epidemic expenses and the deterioration of business environment were the reasons for this result.

4.6 Limitation

This study may have some limitations and shortcomings. First, this thesis uses the quotation data of 132 semiconductor companies from the Guotaian database, which may not represent the development of all semiconductor companies in the whole Chinese market. Second, this research lacks of a comprehensive job in literature collection. Third, the research is rather single-method, and multiple methods should be used to analyze the correlation of each factor. Moreover, more factors ought to be taken into consideration to improve the performance of the model.

5. Conclusion

In summary, this paper investigates the semiconductor industry based on a five-factor model. Specifically, we selected two years before and two years after the epidemic, a long-time span, while the selected companies cover the mainstream semiconductor industry companies, which can reflect the overall trend. According to the analysis, the epidemic had an impact on the five-factor coefficients. In terms of regression analysis, the coefficients of $R_m - R_f$, SMB are positive and the coefficients of HML, RWM, CMA are negative. Thereinto, the coefficients of RM-RF increased from 0.872 to 1.114, while the coefficients of SMB, HML, and RWM decreased to different degrees, respectively. Moreover, under the original hypothesis that H_0 is a coefficient of 0, all of them reject the original hypothesis at the 5% significance level, except for the t stat of CMA. Additionally, the original hypothesis (H_0) that the coefficient of CMA is 0 cannot be rejected at 5% level of significance due to the value of t stat of -1.941 after the epidemic. In the future, other research methods can be adopted on the basis of this paper, while the selection of industry-related companies can continue to be expanded. Overall, these results offer a guideline for observing the impact of epidemic factors on the Chinese semiconductor industry.

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