

# Analysis of Four Technology Related Industries Before and After COVID-19 Based on Fama-French Five-Factor Model

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## ABSTRACT

The COVID-19 devastated the U.S. economy dramatically, which broke the largest shrank record from 1947. The U.S. stock market faced a series of huge fluctuations during the pandemic. Due to more stimulated injection policies and online communication demands, the U.S. technology industry faced a structural bull market in 2020. Given that technology-related industries are critical to a country's development, it is worthwhile paying more attention to the impact of the unprecedented COVID-19 outbreak on those industries, especially how assets are priced differently before and after the outbreak. This study investigates and evaluates changes in the Fama-French Five-Factor Model factors before and after the COVID-19 outbreak for four crucial US technology-related industries (namely hardware, software, chips, and lab equipment industries), which provides suggestions regarding investment strategies of the four industries according to the findings. In addition, the Data from the Kenneth R. French Data Library were used to conduct multiple linear regression. The result demonstrates that the pandemic has profoundly impacted these industries, which can be embodied by the change in significant factors (CMA, RMW, HML) in each market, respectively. In contrast, there is no change in significant factors in the lab equipment industry. In conclusion, COVID-19 has altered both the magnitude and significance of multiple Fama-French Five-Factor Model factors for the industries, and investors should adjust their investment strategies accordingly when investing in different industries to benefit from higher stock returns.

**Keywords:** Fama-French Model, COVID-19, Technology-related Industry, Investment Strategies.

## 1. INTRODUCTION

The COVID-19 devastated the U.S. economy dramatically, which ended the longest economic expansion. 31.4% shrank in U.S. economy in the second quarter of 2020 broke the largest shrank record from 1947. Half of the businesses faced temporally shut down, and the unemployment rate peaked at the highest level of 14.8% in April 2020. The fed readjusted the interest rate from 1.25% to near zero.

With the growing market panic due to COVID-19, the stock market faced 5 fusing in 10 days. The coronavirus also generated huge negatives impacts on the United States's financial market until the government secured the Coronavirus Aid, Relief, and

Economic Security (CARES). For example, a series of downward readjustments on the interest rate, 100 billion quantitative easing programme, etc. Many stimulated injection policies forced more and more people to put money into the market, typically for several specific industries, raising the United States' stock market into a structural bull market.

The pandemic reshaped the world by forcing people from offline to online communication. Remote work, social distancing, and series of online services created a huge demand for electronic products and services. The technology industry played an important role in recovering from the negative impacts of the COVID-19 pandemic. Technology stocks became the superstar, especially for those blue-chip technology stocks. The

top 7 technology companies in the United States yielded 3.7 trillion dollars market value in 2020, equivalent to the United States' governments' total income in 2020.

The Capital Asset Pricing Model (CAPM) was developed by Sharpe et al. in the 1960s, which describes the relationship between systematic risk and expected assets' return. As the pioneer of modern financial market price theory, CAPM provides a more useful way to interpret the financial market in many situations than the dividend discount model (DDM) and the weighted average cost of capital (WACC) by taking into account systematic risk and using diversified portfolios. However, the model is criticized for its unrealistic assumptions on risk-free rate, return on the market, ability to borrow at a risk-free rate, and determination of project proxy beta.

To explain the relationship between expected return and systematic risk and to determine the appropriate rate of return of an asset, CAPM (Capital Asset Pricing Model) was developed by Sharpe [1] and Lintner [2], which was a rather successful attempt at first. According to CAPM, the risk premium is a function of market risk premium, and the coefficient beta ( $B_i$ ) measures a stock's sensitivity to market risk. Despite the usefulness of CAPM in showing the relationship between risk and expected return of assets, the model was criticized for overlooking important factors and its limited explanatory power. Jagannathan and McGrattan gathered multiple evidence against CAPM in their research. They reported that CAPM misses several significant factors such as firm size and the ratio of book-to-market equity, which seem to explain cross-sectional variation in average asset returns better than beta [3].

Realizing the limitations of CAPM, Fama and French developed Fama and French three-factor model (FF3F) as an alternative for asset pricing [4]. FF3F extended the original CAPM by including two more important risk factors, SMB (the size premium) and HML (the value premium), to capture more variation in the market and increase the explanatory power of the model. FF3F was applied in studies, and some evidence suggested that it has strong power and robustness. Basiewicz and Auret used the Fama and French three factor model (FF3F model), the CAPM, and the APT to test the value and size effect in the Johannesburg Stock Exchange (JSE) 's stock market. Time-series tests were carried out by using grouped data and ungrouped data. Basiewicz and Auret found that the FF3F model has an accountable power role in a time-series test on grouped data, and the market capitalization (size) has shown significant power. In the test on ungrouped data, the BE/ME ratio loses its prophet role in pricing errors. Those indicate that the FF3F model has high power in JSE's stock market [5]. Moreover, Sehgal and Balakrishnan re-examined the relation between average

returns and firm characteristics (size, value, and their alternative measures) and the Fama French model (FF3F model) by using the BSE-500 index data on 465 companies from 1996 to 2021. The result confirmed the robustness of the FF3F model, which shows the strong size and value effects in India, and FF3F indeed does a better job than CAPM. However, the FF3F model cannot explain some abnormal returns missed by CAPM [6].

Fama and French proposed Fama French five-factor model (FF5F) in 2015, adding two more factors to the original FF3F, namely RWM (profitability) and CMA (investment) [7]. Comparisons between FF3F and FF5F have been made in empirical studies by running tests using the two models, and it was shown in research that FF5F performs better than FF3F. Ishtiaq et al. applied both the Fama-French three-factor model and five-factor models to the emerging Pakistan stock market, aiming to determine the best model to price the Pakistani stocks. The study was based on a sample of the KSE-100 index of companies for the period between 2007 and 2015. Regression results indicate that the Fama-French five-factor model is better than the three-factor model in capturing the portfolio return patterns related to the size, value, profitability, and investment in the Pakistan stock market. In particular, the five-factor model captured the risk levels associated with firms' characteristics and market portfolio returns fluctuations in pricing the stocks. Therefore, FF5F is proven to be an effective model to apply in security selection for portfolio formation and to calculate the required rate of return on investment [8]. Research carried out by Ragab et al. aimed to find out how financial assets are priced in the Egyptian stock market. Both Fama and French three-factor and five-factor models were applied with the time-series regression. Three sets of portfolios were used as test assets to find relationships between Egypt's stock market returns and size, the BE/ME ratio, operating profitability, and investments. Results reveal that the most significant effect is the size effect, and the five-factor model offers a complete explanation of the stock returns in the Egyptian stock market [9].

In the last year or two, the effect of the COVID-19 outbreak on the economy has been the center of discussion among research, and empirical studies using FF5F were conducted to test the efficiency of the model and the effects of the pandemic. To better understand the efficiency of FF5F during the pandemic, Sun investigated the efficiency of FF5F using data adapted from Kenneth R. French's data library, and goodness of fit (R-squared) was taken to indicate the efficiency of the model. It was shown that there had been an obvious increase in R-squared after the outbreak, which infers an enhancement of the FF5F's ability to explain industry returns during the pandemic. Moreover, the model result shows that when the news of the COVID-19 outbreak spread, market risk premium, size, and value factors

dropped considerably, while profit and investment factor kept their stability. The evidence also suggests that most of the industries from 49 industries experienced changes in their Fama-French factor nature before and after the COVID-19 outbreak, and no industry can avoid being influenced by the pandemic [10]. Furthermore, FF5F was applied in research on the effect of COVID-19 on the service industry. Result reveals that COVID-19 indeed has negative impacts on the service industries, and business with robust profitability generally performs better and generates more returns during the pandemic [11]. As the cornerstone for the prosperity of many countries, the hardware industry's development before and after the COVID-19 pandemic was studied by Liu using the FF5F. It was found that the outbreak of COVID-19 has not only impacted the hardware industry negatively but also lead to stimulative effects such as making the whole industry less sensitive to fluctuations in the market [12].

Apparently, the COVID-19 pandemic has caused many unprecedented changes and posed threats to the survival of many industries. It goes without saying that asset pricing has become even more important during such a special time. Since empirical studies suggest that FF5F indeed is a valid and relatively efficient model to apply when we wish to explain the return of assets, this paper will focus on making use of this model to analyze data on four selected crucial industries in the US economy, namely hardware industry, software industry, chips industry, and lab equipment industry. Changes in the nature of factors in the model for these industries before and after the COVID-19 outbreak will be indicated and evaluated.

## 2. METHOD

CAPM or Capital Asset Pricing Model (CAPM) is a one-factor model that describes the relationship between systematic risk and the expected return for assets. It considers several assumptions and indicates how the risk of investing in a particular asset defines the amount of return the investor will gain out of it. The equation given by the model is as follows:

$$R_i - R_f = \beta_i (R_m - R_f) \quad (1)$$

In this equation;  $R_i$  is the expected return of an investment;  $R_f$  is the risk-free rate of return on investment;  $\beta_i$  of investing in a financial asset is the sensitivity of stock  $i$  relative to the excess return on a market portfolio;  $R_m$  is the average rate of return in the capital market, and  $(R_m - R_f)$  is the market risk premium, i.e., the amount over and above the return that you will get if you invest in a risk-free financial asset. Note that the risk-free rate of return in the CAPM formula represents the time value of money. The other

variables in Equation (1) account for the investor taking on additional risk.

Although the CAPM was generally accepted as a useful tool for security pricing, empirical studies found contradicting evidence as there were two other well-known patterns in average returns left unexplained by the model. Therefore, the Fama-French three-factor model was proposed. The formula suggested by the Fama-French three-factor model is given below:

$$R_i - R_f = \beta_m (R_m - R_f) + \beta_{SMB} SMB + \beta_{HML} HML \quad (2)$$

In addition to the market factor (market premium) suggested by the CAPM model, the three-factor FF model introduced two new factors. The first new factor considers the size premium of firms (Small Minus Big or SMB), which says that smaller firms would outperform larger ones in the long run. The second new factor is sometimes referred to as the 'value factor' (High Minus Low or HML), which accounts for value stocks with high book-to-market ratios that generate higher returns than growth stocks with low B/M ratios over the long term.

Subsequently, researchers have identified additional factors that seem to exhibit a strong relationship with average returns. Novy-Marx suggested that profitability measured by gross profits-to-assets also plays a vital role in predicting average returns [14]; Aharoni et al. showed an important relationship between expected investment and stock returns [16].

As a result, the Fama-French five-factor model was constructed in 2015, where the earlier three-factor model was extended with two other factors: profitability and investment. The new five-factor FF model is as follows:

$$R_i - R_f = \beta_m (R_m - R_f) + \beta_{SMB} SMB + \beta_{HML} HML + \beta_{RMW} RMW + \beta_{CMA} CMA \quad (3)$$

The profitability factor, RMW (Robust Minus Weak), measures the difference between the average returns of companies with robust and weak operating profitability; and the investment factor, CMA (Conservative Minus Aggressive), accounts for the difference between the average returns of firms that invest conservatively and those that invest aggressively. Many studies have proven the effectiveness of the five-factor FF model and that it indeed performs better than the three-factor FF model in explaining expected stock returns. For example, using the test suggested by Gibbons et al. [17], researchers revealed that the five-factor model improved the explanatory power of the average returns of stocks relative to the three-factor model.

### 3. RESULTS

The Fama-French five-factor model was used to study the changes in market risk, book-to-market ratio, industry size, profit, and investment style from before to after the COVID-19 pandemic in four industries - hardware, software, chips as well as lab equipment.

Data obtained in this paper were from Fama/French 5 Factors (2×3) [Daily] and 49 Industry Portfolios [Daily] in the Kenneth R. French Data Library.

After performing multiple linear regression in the period before and after the pandemic (2019.05 – 2020.02 and 2020.03 – 2020.12), the following results were displayed:

**Table 1.** Multiple linear regression results of four industries before and after the outbreak

Industry	Period	Statistics	Mkt-RF	SMB	HML	RMW	CMA
Hardware	Before	Coefficient	1.2887	0.1611	-0.0340	-0.0678	0.3967
		P-value	0.0000	0.2290	0.8041	0.7615	0.1347
	After	Coefficient	1.0417	0.1083	-0.1078	0.0949	0.4699
		P-value	0.0000	0.2327	0.1490	0.5300	0.0159
Software	Before	Coefficient	0.9821	0.4673	-0.3880	-0.0953	-0.5799
		P-value	0.0000	0.0000	0.0000	0.3629	0.0000
	After	Coefficient	0.9464	0.5549	-0.1776	-0.3452	-0.6904
		P-value	0.0000	0.0000	0.0001	0.0002	0.0000
Chips	Before	Coefficient	1.0070	0.6781	0.0042	0.2492	-0.0954
		P-value	0.0000	0.0000	0.9631	0.0981	0.5892
	After	Coefficient	0.9595	0.6583	-0.1107	-0.0661	-0.0683
		P-value	0.0000	0.0000	0.0470	0.5603	0.6373
Lab equipment	Before	Coefficient	0.9432	0.4552	0.0833	0.0253	-0.0203
		P-value	0.0000	0.0000	0.3167	0.8517	0.8992
	After	Coefficient	0.8960	0.5171	-0.0174	-0.1983	0.0934
		P-value	0.0000	0.0000	0.8033	0.1612	0.6056

As shown in Table 1, for a 5% significance level, it is observed that the market risk factor (Mkt-RF) is the only one that is significantly different from zero in the hardware industry. The results indicate that all factors except RMW contribute to the returns of stock in the software industry. As for the chips and lab equipment industry, both Mkt-RF and SMB are significant factors before the pandemic. After the pandemic, CMA turned into a new significant factor in the hardware industry. Its positive coefficient demonstrated that a more conservative investment style would generate higher returns. In the software and chips industries, RMW and HML became significant, respectively. The lab equipment industry is different from others as there is no change in significant factors after the epidemic.

### 4. DISCUSSION

#### 4.1 Hardware industry

For the hardware industry, only the Mkt-RF is a significant factor before the COVID-19 pandemic, in which the coefficient is 1.29 and the t-statistic is 18.16. However, the factor becomes more strongly significant after the pandemic, in which the coefficient is 1.04, and the t-statistic is 29.65. It shows a lower coefficient but a stronger relationship. The hardware industry seems to be more sensitive to the fluctuation of the whole market ( $\beta_m > 1$ ).

The special nature of the hardware industry is that it has a high technical threshold to come in. Still, all companies in the industry are facing the around same level technical bottleneck. It delivers a solid message that one of the hardware companies overcome any technical difficulties, it becomes bellwether then, making the stock price rise. But if the company finds it hard to keep its bellwether position due to other companies' innovations, it will lose its position and cut its stock price. When the coronavirus outbreaks, remote work, social distancing, and series of online services created a huge demand for electronic products and services. The smartphone shipment volume increases 27% year over year in H1 2020 in the United States as 5G is pushed to upgrade and 5G smartphone met a heavy discount. As the top-sellers, Apple and Samsung have a 53% and 17% increase year over year in the premium segment [18]. The decreasing coefficient indicates the industry will have a more stable competitive environment due to slow technology development in coronavirus and increasing demand for electronic devices. Maybe the technical monopolies happen somewhere in the hardware industry. According to the increasing t-statistic in  $\beta_m$ , the relationship between the market risk premium and return will be stronger.

The difference in returns between firms with low and high investment policies (CMA) shows a significant but weak relationship with the market return after the

pandemic rather than before the pandemic. The coefficient of CMA is 0.47 and significant after the pandemic. Owing to the economic downturn after COVID-19, many companies in different industries faced huge losses in the period. Hence, conservative firms with low investment policies could control losses and save valuable cash flow to gain higher profits than aggressive firms with high investment policies.

SMB, HML, and RWM are redundant variables in the hardware industry, showing that the market has no clear inclination towards size effect, value effect, and profitability.

#### **4.2 Software industry**

As suggested by Table 1 for the software industry, before the pandemic, four factors Mkt-RF, SMB, HML, and CMA are statistically significant, but not RMW; after the COVID-19 outbreak, all factors in the model became statistically significant. Each factor's nature and changes will be discussed in more detail in the following.

Since the coefficients of Mkt-RF are positive for both periods (0.98 and 0.95), the change direction in the market is in line with that of the software stock. Coefficients being less than 1 in both periods suggest that the sensitivity of the software industry to market shocks is relatively low. The software industry is critical in our increasingly digitalized world. Its robustness and necessity make it hard to sensitive to market fluctuations. In addition, due to the increasing demand of businesses for accelerating digital transformation, the software industry is one of the few industries that thrive in the pandemic. This resulted in the software industry being slightly more resistant to market changes, which explains why the coefficient is closer to zero after the pandemic.

The coefficient of SMB reflects the response of the stock to the size premium of the market. The coefficients before and after the COVID-19 outbreak are both positive (0.47 and 0.55) and significant, with the latter being larger. This infers that the software industry favors small-sized companies in both periods, especially after the outbreak. One explanation for this phenomenon is that small companies in the software industry may make better innovations than the big ones due to diminishing marginal returns of labour in the sense of innovation. Wu et al. showed that across the period 1954–2014, smaller teams have tended to disrupt technology with new ideas and opportunities. In contrast, larger teams have tended to develop existing ones, suggesting that innovation is indeed one advantage of small firms [19]. Innovation is essential for technology development and breakthrough. Hence that's why small-sized companies may be favored over the

large ones, especially when there are great changes in the environment like the pandemic.

The response of the stock to the book-to-market ratio premium is indicated by the coefficient of HML, which is negative for both periods (-0.39 and -0.18), but it is closer to zero after the outbreak. This indicates that the industry favors a low book-to-market value company or stock, i.e., growth companies and stocks. Growth companies are generally less risky than value companies as they are less sensitive to adverse economic conditions than the market; also, the values of growth businesses are overestimated by the market. Before the pandemic, there was a rise in the software industry, and the expectation towards software companies was high, which brought about an overestimation of business values in the industry. After the outbreak, people lost confidence in almost all industries. This caused a slight tendency to prefer value stocks in the software industry, which is revealed by the increase in coefficient.

The coefficient of RMW is redundant before the pandemic but later became significant with a negative value (-0.35). This indicates that COVID-19 has led to a higher weighting of profitability in the software industry, and businesses with small profit margins appear to perform better during the pandemic. This is unexpected as usually, companies making large and robust profits in the industry would have the financial power to thrive under difficult situations. However, this result may stand because firms with small profitability are typically small firms that are better at innovation. This quality of small firms enables them to perform better than large companies even if large firms have robust profitability.

CMA factor shows how stock responds to the investment premium, and this coefficient is negative before and after the outbreak (-0.58 and -0.69). This result infers that the industry favors aggressive investment strategy over conservative one in both periods. In addition, the coefficient after the outbreak is more negative than before, which implies that the industry values aggressive investment strategy even more. The reason behind this may be that with the rapid development of the software industry, investors attempt to seize the opportunity of generating return by making aggressive investments in software stocks, especially when there is a high demand for working from home (hence computer software support) during the pandemic.

#### **4.3 Chips industry**

As shown in Table 1, Mkt-RF is a significant factor both before and after the pandemic. From the period before the COVID-19 outbreak, the market risk coefficient is about 1.01, indicating that the chips industry is almost as sensitive as the market. However,

its value dropped to 0.96 in the next few months, illustrating that the chips industry became more stable and less sensitive than the market. In fact, the epidemic's impact on the chips industry is relatively small due to the following two reasons. Firstly, on the upstream of the industry, the design of chips can easily be conducted by developers remotely. Therefore, staying at home due to the pandemic would not seriously jeopardize the efficiency of these firms. Secondly, the manufacture of chips is technology-intensive with only a few labour. Hence most production lines can still operate normally. Thus, the sensitivity of the chips industry to the market fluctuations was decreased.

Another significant coefficient is the size factor (SMB), with values 0.68 and 0.66 before and after the pandemic, respectively. Evidently, there is not much variation in this factor. These two positive values reveal that the market favors small-cap companies over large-cap companies in the chips industry. As long as small-cap firms master the core technology, they have much greater potential to grow, and therefore investing in them could generate higher profit.

In contrast with SMB and Mkt-RF, which are significant in both periods, the coefficient of HML is only significant with a value of -0.11 after the start of the epidemic. This indicates that investing in corporations with low book-to-market ratios, i.e., growth stocks, could yield higher returns. Two main reasons contribute to this change. In the first place, the pandemic has made the market even more unstable. In such a situation, most investors would choose more prudent strategies due to the unpredictability. Thus the less risky growth stock is favored by the market. Besides, the work-from-home trend has led to an increase in demand for computing devices and thus chips. According to a report on *Fortune Business Insight*, "As per the Q2 2020 results of LG Electronics, the percentage share of notebook and tablets increased to 29% in Q2 from 20% in Q1 2020" [20]. Since companies with low book-to-market ratios are generally those with better financial performance. They could react to this increase in demand rapidly and reach higher revenues, which attracts more investors.

RMW and CMA are two redundant factors, in this case, showing that the market has no clear inclination towards the profitability or the investment style of firms in the chips industry.

#### **4.4 LabEq industry**

Two factors appear significant in explaining asset returns (both before and after the outbreak of COVID-19) in the industry of measuring and control equipments. The first factor is the Mkt-RF factor. It is designed to capture the sensitivity of the industry

relative to the whole market. The coefficients of Mkt-RF are less than 1 but very close to 1 in both periods. This infers that the sensitivity of these stocks is consistent with the market.

There can be many reasons behind why the expected asset returns in the industry move approximately in line with changes in the whole market. One reason can be that demands for laboratory apparatuses are usually based on demands for other products such as for a particular engineering project, and the demands for engineering projects often depend on people's income and other economic conditions. Consequently, the returns of the stocks in the industry for laboratory equipments (LabEq) tend to increase or decrease in line with overall economic expansion or contraction.

SMB is the second significant factor in explaining the expected returns of stocks in the LabEq industry—both before and after the global pandemic. In other words, small-cap stocks in the industry often receive higher asset returns. Influenced by the pandemic, the coefficients of SMB have increased from 0.46 to 0.52, which indicates a stronger relationship between SMB and expected asset returns, providing a much-motivated incentive for investors to invest in small-cap stocks.

There may be several reasons behind the significance of SMB for predicting asset returns in the industry. One reason can be that smaller firms are more flexible and can react quickly to opportunities than larger businesses. They may be able to adjust their production line for particular measuring equipment rapidly to meet higher demands. This advantage of small firms continues to exist even during the pandemic, which becomes especially crucial as there may be much fewer opportunities to capture. In addition, as small businesses tend to focus on producing a relatively narrow range of products (in this case, laboratory equipments), they may benefit from their expertise in a particular field, hence working more efficiently and earning higher profits.

The other three factors, namely RMW, HML, and CMA, appear insignificant in explaining asset returns in the industry of measuring and control equipments; this insignificance was not affected by COVID-19. Hence little attention was given to these factors.

## **5. CONCLUSION**

This study focuses on analyzing the impact of COVID-19 on hardware, software, chips, and lab equipment industries based on the Fama-French Five-Factors Model and Data from the Kenneth R. French Data Library.

According to the results, investors willing to invest in the four industries would be informed respectively.

For the Hardware industry, firms with conservative investment policies and large profit margins should be preferred. For the Software industry, investors should focus on firms with weak profit margins and aggressive investment strategies. For the Chips industry, stocks from low market capitalization companies or growth stocks should be favoured more. For LabEq industry, investors should also focus on small-cap stocks while frequently monitoring market movements.

As COVID-19 still prevails, to make profitable investments, investors need to be well-informed of the impacts such an unprecedented event can bring to those technology-related industries.

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