Research on the application of Fama and French three-factor and five-factor models in American industry

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Abstract. By conducting ordinary least square estimations using the Fama and French Three-Factor and Five-Factor models on thirty U.S. based industry portfolios, the significant rate of all the variables is compared. Using the comparison, the impacts of the COVID-19 Pandemic on the markets and the Fama and French models are significant. As a result, the significance level of all the independent variables has increased during the COVID-19 Pandemic. The Five-Factor model fares a more substantial increase in efficiency during the Pandemic, and some variables, such as HML and CMA, see tremendous changes. The market becomes less sophisticated during the Pandemie, and the Fama and French Five-Factor model may be more suitable for estimation under certain market environments, contrary to many previous studies.

Keywords: Fama-French model, COVID-19, Significance level, CAPM, Ordinary least square estimator.

1. Introduction

The single-factor model (such as the CAPM model) uses the simple ordinary least squares to value different industries' expected returns. Sharpe and Linterner developed Capital Asset Pricing Model (CAPM) to study the relationship between the expected return on a risky asset and the market risk premium based on the mean-variance model. The model illustrates the reward must be equal to the risk-free rate plus the risk-adjusted degree of risk relative to the total market portfolio—the higher the degree, the higher the additional compensation to be received. The risk premium's size is related to the beta size, which measures an industry's volatility relative to the total market. An early empirical analysis focused on Sharp's prediction of the intercept and the CAPM model's slope, and thus two questions occur. Firstly, the beta estimation is inaccurate, especially for a single asset whose intercept of estimators is lower than the actual intercept term. And the beta is opposite based on regression analysis as well. Secondly, heterogeneous results can be found due to the significance of portfolio selection [1]. The limitation of beta is exposed, which does not work well in the empirical analysis. Thus, Fama and French add two limitation factors--size factor (SMB) and Book-to-market ratio factor (HML) to the three-factor model to even better explain the expected return of the stock, propose to increase the accuracy of beta term, and explain the size effect and value effect, which CAPM fails to solve in 1993. The empirical results, as a whole, are reasonably consistent with the Fama-French three-factor model [1]. Then, Fama and
French introduced a five-factor model, adding two limitation factors (RMW and CMA) to the three-factor model to observe the return premium associated with profitability and investment [2].

Currently, COVID-19 has become a global shock, which means a global recession is inevitable, reflected in limited or even declining GDP growth in all countries, with some countries experiencing GDP declines of more than 15% [3]. There is no historical precedent for the impact of COVID-19 developments and policy responses on the U.S. stock market. The unprecedented stock market reaction to COVID-19 is unexplained by the four meltdowns in U.S. stocks from March 9th to 18th. However, it is obvious that some policies, such as travel restrictions, business closures, and social distancing mandates, bring great economic damage to address this health crisis [4]. Under an epidemic, the question arises that 3-factor or 5-factor Fama French model is more accurate in terms of the change in average U.S. stock returns over the epidemic period.

The Fama-French three-factor model is more appropriate for the U.S. stock market than the CAPM. Gregory and Sanjay concluded that U.S. stock returns are generally influenced by the pervasive market, size, and value factors because of the cross-sectional dispersion of average returns. However, whether the size and value factors are pervasive in explaining the risk of a wider range of portfolio is still a problem. For example, they find equity returns in the Indian market can be affected by two factors except for the value factor. Therefore, the three-factor model is only applicable in specific market environments. Compared with the three-factor model, does the five-factor model have more general suitability than the three-factor model in most markets? Eoghan et al. reckon the five-factor model can be the least-bad model and constitute a marginal improvement compared to the three-factor model. In some cases, for example, five-factor model has better explanatory power for the above three sectors in China than the three-factor model [5]. The five-factor model better explains Australian equity pricing from 1982 to 2013 because the model is able to explain more asset pricing anomalies, including the Australian three-factor, earnings and investment factors, and the U.S. five-factor because of the close relationship of the political economy and geographic location between the U.S. and Australia. The five-factor model in Australia better addresses the mispricing of the three-factor model before and also reflects the relationship between Australia and the Americas, which has a realistic basis [6]. In 2020, with the world encountered the unanticipated COVID-19, Dominik and Wang found that COVID-19 has a negative impact on the goodness of fit of the five-factor model in the U.S., which leads to a significant drop in R-squared in the first three months of the outbreak. However, as the outbreak is still ongoing, the change in R² needs to be further researched.

The epidemic has caused dramatic changes in the stock market. The purpose of this paper is to explore how the Fama-French three-factor and five-factor models reflect the current U.S. stock market with 30 industries, discuss which model is more applicable to the U.S. stock market with the data collected now, and analyze the relative changes in each factor before and during the COVID-19.

2. Fama-French Mode

Sharpe, Linter and Mossin developed the model of pricing of capital assets (CAPM), and it was widely used to predict stocks' returns before the introduction of the Fama & French models [7-10]. Eugene Fama and Kenneth French instituted the Fama & French models motivated by the study of Banz, which bestows a more precise method to forecast stocks' return [11]. They found that small stocks in terms of market capitalization and with a low P/B perform superior to the overall market with greater efficiency. Therefore, they incorporated size risk and value risk factors into the capital asset pricing model:

\[
R_{it} - R_{ft} = \alpha_{it} + \beta_1(R_{Mt} - R_{ft}) + \beta_2SMB_t + \beta_3HML_t + \epsilon_{it}
\]

where \(R_{it}\) and \(R_{ft}\) represent the risk-free return rate and market return of a portfolio, respectively, and their difference indicates the expected return of a portfolio. The value of Small Market Valuation minus Big is the Epsilon, and the Delta is High Book Value minus Low to Market Ratio. Large stocks produce lower returns than small stocks in the long run, whereas value stocks have generated higher returns than growth stocks, even though small stocks and value stocks contain more risk. Fama and
French also proposed integrating profitability and investment into the three-factor model and producing a new five-factor model since variations in average returns related to probability and investment are absent in the three-factor model. With the new variables added to the model, the new equation becomes:

\[ R_{it} - R_{ft} = \alpha_t + \beta_t (R_{Mt} - R_{ft}) + S_t SMB_t + h_t HML_t + r_t RMW_t + c_t CMA_t + \epsilon_{it} \]  

(2)

New variables \( RMW \) and \( CMA \) are introduced in the model; they represent the return spread of the most profitable firms minus the least profitable ones, and the return spread of firms with different investment strategies. The tests carried out by Fama and French indicated that the value factor of HML is redundant for the description of the average returns if profitability and investment factors have been incorporated into the equation [12]. However, there are drawbacks to the five-factor model, Valiet considered the two additional factors to be a significant difference from the three-factor model, and he believes with the new factors to interact with each other, it is more difficult to summarize the cross-section of the stocks' returns [13].

Conducting empirical tests on various industry portfolios using the Fama & French Model before and after the COVID-19 outbreak can show how the financial market reacts to a global event. French created a website that provides useful data to conduct empirical tests. To ensure diversified test results, a 30-industry portfolios data set is selected. It contains the average return of 30 different industry portfolios, and it consists of the data from 1926 to 2020. Therefore, the historical data can be fitted into a simple regression model, and the data is analyzed.

3. Results

Each industry's expected excess returns are regressed onto the factors of Fama & French three-factors and five-factors models, respectively, using the OLS estimations.

### Table 1. Significance rate of SMB and HML at 10% significant level

| Significance rate of SMB and HML at 10% significant level | percentage |
|----------------------------------------------------------|------------|
|                                                          | SMB | SMB | HML | HML |
|                                                          | Significant Rate Pre Covid | Significant Rate Post Covid | Significant Rate Pre Covid | Significant Rate Post Covid |
|                                                          | 0.9 | 0.93| 0.7 | 0.8 |

The results indicate that the explanatory variables, SMB and HML, are more efficient after the COVID-19 outbreak when explaining the expected excess return of the market. To further consolidate this claim, a similar test is constructed on the Five-Factor model.

### Table 2. Significance Rate of SMB, HML, RMW and CMA Estimators at 10% Significant Level

| Significance Rate of SMB, HML, RMW and CMA Estimators at 10% Significant Level | Percentage |
|-------------------------------------------------------------------------------|------------|
|                                                                              | SMB | SMB | HML | HML |
|                                                                              | Significant Rate Pre Covid | Significant Rate Post Covid | Significant Rate Pre Covid | Significant Rate Post Covid |
|                                                                              | 0.9 | 0.97| 0.47| 0.77|
|                                                                              | RMW | RMW | CMA | CMA |
|                                                                              | Significant Rate Pre Covid | Significant Rate Post Covid | Significant Rate Pre Covid | Significant Rate Post Covid |
|                                                                              | 0.37| 0.4 | 0.2 | 0.4 |
Table 2 also demonstrates the improvement of the efficiency of the explanatory variables during Covid-19. All the variables see an increase in efficiency; however, HML and CMA see the most significant increase in explanatory power during the Pandemic.

4. Discussion

This paper compares the Fama & French models’ explanatory power for 30 major industries in the U.S changes before and during the COVID-19 Pandemic. There is a clear improvement in explanatory power using the Fama & French models during the Pandemic; the evidence is compelling, and one theory that may explain the results is that the COVID-19 Pandemic may pose restrictions in the market that alter the behaviors of consumers and producers, leading to a smaller exogenous error term in the models. Badar et al. collected daily changes of the stock index for 80 countries from 22 January to 17 April 2020 and concluded that the impact of the epidemic on stock markets could be generally divided into several phases: Firstly, the decline in stock market returns [14]. Secondly, weakened negative reaction to the growth in COVID-19 confirmed cases because of the stringent government social distancing measures. Then, a gradual recovery of the stock market and further weakened negative reaction to the growth in COVID-19 confirmed cases because of government containment and health policies. Finally, increasing equity returns due to government support.

The three-factor model sees an improvement in efficiency, yet the improvement is not as significant as the five-factor model. In the three-factor model, the significant rate of the two variables SMB and HML increases by 3.7% and 14.29%. This result indicates that the three-factor model has great efficiency when explaining the market's expected excess return before and during the Pandemic. On the other hand, the five-factor model sees an increase of 64.29% and 100% in significance rate for HML and CMA, which leads to an excellent refinement of efficiency during the Pandemic. This result indicates the five-factor model might not be a great instrument when the market is complex but becomes a great instrument when the market is simplified.

The variable HML is present in both the three-factor and the five-factor model; however, its significance rate dwindles in the five-factor model, indicating its redundancy in the five-factor model. The speculation is further supported by Fama and French, who concluded that removing the addition of HML does not improve the interpretation of average returns based on U.S. data from 1963-2013. In regressions of each of the five factors on the other four factors, the interception produces more than three standard deviations from zero for the other three-factor regressions, but less than one standard deviation for the regression with HML. The large average HML return is absorbed by the exposures of HML to the other four factors, especially the profitability and investment factors.

The new variable CMA is usually recognized as redundant as well, especially in specific markets, such as Europe and Japan from 1990-2015, as Fama and French said. However, its significance rate also improved drastically, which means the population's behaviors during the Pandemic can ameliorate CMA's explanatory power in the five-factor model. Further studies may be conducted on this matter to determine the best condition when implementing the CMA variable.

The significance rate of SMB and RMW increased during the Pandemic, though the changes are not notable. There are still some positive effects on efficiency from the Pandemic. The market simplifies during the Pandemic, and this can be backed up by the increase in the value of residuals squared. After all, the Pandemic brings efficiency to the Fama & French models.

5. Conclusion

Asset pricing has always been a hot topic in academic circles. The research on the relationship between investors' risk and the stock expected return has attracted much attention. With the deepening of the research, the relevant theoretical models have undergone many changes. Based on the Fama-French three-factor model and five-factor model, this paper analyzes the changes of the 30 industries in the US stock market before and during COVID-19. The results show that the Fama-French model has greatly improved the matching accuracy of various sectors of the US stock market after the epidemic. In addition, the significance ratio of multiple factors has been significantly improved, indicating that the epidemic
conditions have a positive effect on the strength of the model. This kind of obvious change may be affected by many factors such as epidemic situation, quantitative easing, and US presidential election, which also provides a reference for investors to make decisions.

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