Research on the Influence of Covid-19 on U.S. Oil Industry Based on Fama-French 5-Factor Model

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Abstract: This article explores U.S. investors' investment decisions in the oil industry in response to three major events during the COVID-19 pandemic, which are the outbreak of the COVID-19 epidemic, the successful achievement of the Pfizer vaccine, and the end of the COVID-19 epidemic. The data, ranging from January 2019 to November 2022, is processed with Fama-French 5-factor model and the fitting results of the 5-factor model of these four periods of time are derived by multiple linear regression. The significance of each factor of the model will change due to different choices of investors, especially SMB, RMW and CMA. In different periods of the epidemic, investors will not pay attention to the market value, ROE and total asset growth rate of oil companies because of events that are not conducive to the oil industry, such as the US interest rate hike and the Russia-Ukraine war. In addition, investors will also refocus on these indicators when they hear news that is positive for the stock market, such as the successful development of Pfizer's vaccine or a cut in U.S. interest rates. By conducting comparisons and analyses, this article highlights the fluctuations in the stock market within the oil industry. The insights gained from this analysis can prove beneficial for both investors and government officials when formulating policies and making informed decisions.

Keywords: COVID-19, Oil Industry, U.S. stock market, Fama-French Model

1. Introduction

Since the end of 2019, the outbreak of the COVID-19 epidemic has caused serious losses to the economies of countries around the world, and it has also posed a serious threat to the lives and health of people around the world. Shortly after the outbreak of the epidemic, the stock market entered a period of violent shocks and began to gradually recover. In addition, factors such as world economic recession and travel ban will inevitably have a great negative impact on the demand for oil. In response to the epidemic, the United States has successively implemented policies of lowering and raising interest rates, coupled with the successful development of vaccines in the later stage, and the outbreak of the Russia-Ukraine war, all of which have greatly affected oil prices. The increase in crude oil price will increase the production cost of crude oil-related industries, thereby reducing the profits of these industries, resulting in a decrease in the output of enterprises; the increase in crude oil price may also increase the price of its complementary products, such as gasoline, diesel and other consumer goods. This will increase the pressure on consumers to buy

stocks, which in turn will lead consumers to reduce their investment in the stock market. Moreover, crude oil price fluctuations usually cover economic, political, military and other fields, and such information will have a huge impact on investment decisions.

In their examination of the effects of COVID-19 on economic activity, Eichenbaum, Rebelo, and Trabandt discover that there is a necessary trade-off between the severity of the recession and the death toll. According to Ma, Rogers, and Zhou (2020), developing nations are most likely to be negatively impacted by COVID-19 to a greater extent than developed nations. Countries with more aggressive government fiscal policies have a greater potential to reduce negative GDP growth [1]. Moreover, Zhang et al. examine the quick spread of COVID-19 around the world and its effects on the financial market. The authors find that unlimited quantitative easing (QE) and zero percent interest rates can assist in recouping recent losses in the financial markets [2].

Based on daily news headlines, Baker et al. study the US stock market volatility and discover that COVID-19 has a overwhelming impact on stock market volatility, particularly after 24 February 2020.

Ramelli and Wagner conducted an event study to examine the impact of COVID-19 on the stock prices of US companies during three subperiods from January through 20 March 2020. They found that companies with China-related businesses had significantly negative returns during the outbreak period and experienced negative abnormal returns during the incubation period [1]. Moreover, during the "feverish" period, investors and analysts expressed significant concerns regarding corporate debt and liquidity. Yan, who analyzed the market response to COVID-19 for A-share stocks in China from 20 January 2020 to 7 April 2020, reported that while stock returns were adversely impacted by COVID-19, they rebounded every 10 days. He also discovered that larger companies were more resilient to the shock due to their greater resources or monopoly power, and suffered less from supply chain disruptions [1].

In recent literature, COVID-19's effects on the energy markets have become a focus of attention. Bakas and Triantafyllou explore the impact of the global pandemic on the volatility of gold and crude oil prices. Their findings suggest that while COVID-19 has negatively impacted the oil market, gold exhibits a favorable but less significant association [3]. Ben Amar et al. examine the implications of commodities and stock price spillovers between oil-producing and consuming nations during the COVID-19 crisis, and demonstrate that the degree of important interdependence has reached its peak. Meanwhile, Sharif, Aloui, and Yarovaya investigate the relationships between COVID-19, the oil, and the stock markets using a temporal frequency domain approach [3]. In a separate study, Wang, Shao, and Kim (2020) examine the impact of COVID-19 on the cross-correlations between the crude oil and agricultural futures markets, and discover a significant relationship between sugar and oil [3]. Overall, these studies offer important insights into the complex interplay between COVID-19 and the energy markets, and underscore the need for continued research in this area.

More specifically, recent studies on COVID-19 and the energy market, conducted by Narayan, Gil-Alana and Monge, Liu et al., Apergis, look at topics like COVID-19 infections, news about oil prices and political polarization, pandemic and volatility persistence, and the persistence of volatility and find that the pandemic outbreak has disrupted the world's crude oil prices, escalated in increased volatility, and caused conflicts over oil prices. The most well-known studies on market responses to public health emergencies, such as Schell et al., Huynh et al., Goodell and Huynh, Pham and Huynh, have established a link between energy market risk and unprecedented events like the COVID-19 pandemic [2].

This article examines U.S. investors' investment decisions in the oil industry in response to three major events during the COVID-19 pandemic. The three major events were the United States announced the outbreak of the COVID-19 epidemic, the successful development and use of the

Pfizer vaccine, and the United States announced the end of the COVID-19 epidemic. The reaction of investors will be reflected by the changes of constant items, independent variables and coefficients in the Fama-French five-factor model. The application of the Fama-French five-factor model will help investors make better decisions about investing in the oil industry in U.S. stocks in the face of public health emergencies.

2. Method

2.1 Capital Asset Pricing Model

After Markowitz proposed portfolio theory, William Sharpe quantified the relationship between risk and return and proposed the capital asset pricing model in 1964, which argues that the market risk-free rate and the systematic risk taken can determine the expected return of a security. Its general expression is

$$R_i - R_f = \beta(R_m - R_f) \tag{1}$$

R_f represents the risk-free rate; β represents the beta; and R_m represents the market portfolio return.

The capital asset pricing model is very classical and has obvious advantages such as simplicity and ease of use. The model is also characterized by its high practicality. The model allows investors to select and evaluate various types of securities assets based on absolute risk rather than total risk level. This approach solves common problems in investment decisions and is accepted by a wide range of investors in the securities market. At the same time, the capital asset pricing model has many shortcomings and is not perfect. First, the basic assumptions in the capital asset pricing model are almost difficult to be realized, because they are the product of the ideal state. Second, the beta in the model is difficult to determine because of the lack of historical information on stocks. Third, the capital asset pricing model only elaborates the returns of securities traded under equilibrium conditions, but does not explore the detailed construction of the factors influencing the returns of securities [4].

2.2 Fama-French three-factor model

In order to solve the above problems of arbitrage pricing theory, Fama and French developed a three-factor model in 1993 to explain stock returns. The basic assumption of the model is "finite rationality", which is used to make many assumptions including: first, there are a large number of investors in the market; second, all investors have the same security holding period; third, investors only invest in financial assets in the public market; fourth, investors do not have to pay transaction fees and tax costs Fifth, investors have the same view of expected returns, standard deviations, covariances, and security market analysis. At the same time, the core concept of the model is that the excess return of a stock portfolio can be summarized by three factors, namely, the market factor, the size factor and the value factor. The general expression of the model is

$$R_{it} - R_{ft} = \alpha + \beta_1(R_{mt} - R_{ft}) + \beta_2 SMB_t + \beta_3 HML_t + \varepsilon_{it} \tag{2}$$

R_{it}, R_{ft} and R_{mt} represent the return, risk-free rate, and market portfolio return at t; SMB_t and HML_t represent the return on the combination of size and value factors at t; β_1, β_2, and β_3 represent the constant term coefficients of the market factor, size factor, and value factor, respectively; represents the intercept term coefficient; and ε_{it} represents the residual term coefficient at t.

In the U.S. stock market, the three-factor model has a high level of explanation of stock excess returns and a strong ability to elaborate the relationship between the three factors. The model has also been used extensively in empirical analysis while being tested and improved by domestic and foreign economists. However, there may be certain risk factors that are ignored in the three-factor model, so it is not perfect either. For example, the three-factor model cannot explain the extent to which the level of company earnings and investment style affects the excess returns of stocks.

2.3 Fama-French five-factor model

Starting from the 1990s, foreign scholars have successively proposed other factors that have a significant impact on stock excess returns, such as liquidity factor, earnings level factor, and investment style factor. In this century, Fama and French discovered that there are indeed many unexplained financial anomalies between stock excess returns and the three factors, and after continuous refinement, they constructed a new asset pricing model, the five-factor model, in 2015.

The new model adds the earnings and investment factors to the original model and is designed to analyze the explanatory role played by market risk, size, book-to-market ratio, earnings and investment on the changes in the explained variables, using the average portfolio return as the explained variable. The general expression of this model is

$$R_{it} - R_{ft} = \alpha + \beta_1(R_{mt} - R_{ft}) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 RMW_t + \beta_5 CMA_t + \varepsilon_{it} \quad (3)$$

The return of asset portfolio i at t is represented by R_{it}. Meanwhile, R_{ft} represents the risk-free return. The return of the market portfolio, weighted by market capitalization, is represented by R_{mt}, while $R_{mt} - R_{ft}$ represents the market risk premium. To account for size differences, the size factor SMB_t represents the variation between the returns of the small-cap and large-cap portfolios at t. On the other hand, the book-to-market ratio factor HML_t represents the difference between the returns of the high-book-to-market and low-book-to-market portfolios at t. The earnings factor RMW_t takes into account the variation between the returns of highly profitable and low-profitable stock portfolios at t. Additionally, the investment factor CMA_t represents the difference between the returns of the conservatively biased and aggressively biased stock portfolios at t. Finally, ε_{it} represents the residual with zero mean.

3. Result

Using the aforementioned approach, the data is analyzed for four distinct time periods: January 2019 to March 2020, March 2020 to November 2020, November 2020 to September 2022, and September 2022 to November 2022. Multiple linear regression (MLR) is utilized to obtain the fitting outcomes of the 5-factor model for each period [5].

Table 1 displays the regression results for data prior to the COVID-19 outbreak. In this period, the t Stat for the intercept between January 2019 and March 2020 is not significant, but the t Stat for the other four explanatory variables is significant. This suggests that, during this time frame, the intercept may not have had a meaningful impact on the dependent variable, while the other variables likely played a more important role in explaining the results. Looking more closely, we see that the significance of the t Stat for the other variables underscores their importance in this context, and highlights the need for further analysis to fully understand their contribution. In addition, as Table 2 illustrated by using the Fama-French 5-factor model, for regression results of

data before the successful development of the COVID-19 vaccine, the t Stat of intercept, $R_m - R_f$, SMB and HML stay the same as the last period, but t Stat of RMW and CMA become insignificant [5]. In particular, as Table 3 shows, the t Stat of α, RMW and CMA of the period of time from November 2020 to September 2022 turn to be significant, while that of SMB becomes redundant. According to Table 4, for regression results of data after the U.S. declared the end of the COVID-19 outbreak, the t Stat of intercept and RMW change to insignificant, and the t Stat of be SMB of the period from September 2022 to November 2022 remain redundant.

Table 1: Regression results of data before the COVID-19 outbreak.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
α	-0.135321	0.097506	-1.387826	0.1662
$R_m - R_f$	1.22704	0.082484	14, 87606	0.0000
SMB	1.223223	0.195645	6.25226	0.0000
HML	1.934257	0.18216	10.61843	0.0000
RMW	-0.696841	0.314277	-2.217281	0.0274
CMA	-1.445203	0.397696	-3.63394	0.0003

Table 2: Regression results of data before the successful development of the COVID-19 vaccine.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
α	0.252313	0.256842	0.982364	0.3273
$R_m - R_f$	1.096209	0.125659	8.723656	0.0000
SMB	0.830466	0.300809	2.760778	0.0064
HML	1.161540	0.249266	4.659840	0.0000
RMW	-0.555738	0.517683	-1.073511	0.2845
CMA	-0.127680	0.666078	-0.191689	0.8482

Table 3: Regression results of data after the successful development of Pfizer vaccine.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
α	0.220132	0.092669	2.375456	0.0179
$R_m - R_f$	1.1 93968	0.088569	13.48065	0.0000
SMB	0.183101	0.141778	1.291461	0.1972
HML	1 .359339	0.128371	10.58912	0.0000
RMW	-1.731470	0.150331	-11.51774	0.0000
CMA	0.683819	0.213004	3.210355	0.0014

Table 4: Regression results of data after the U.S. declared the end of the COVID-19 outbreak.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
α	0.194384	0.227799	0.853311	0.3979
$R_m - R_f$	1.1 82653	0.167796	7.048176	0.0000
SMB	0.185117	0.570418	0.324529	0.7470
HML	3.081704	0.557507	5.527650	0.0000
RMW	-0.814066	0. 434506	-1. 873545	0.0674
CMA	-2.374147	0.759437	-3.126192	0.0031

4. Discussion

4.1 Before the outbreak of the COVID-19 epidemic

The oil sector in the U.S. stock market is fully consistent with the Fama-French five-factor model with all five factors significant from January 2, 2019 to March 12, 2020, i.e., before the COVID-19 outbreak.

First, it shows that investors paid attention to all five factors, especially the four factors SMB, HML, RMW and CMA, which means that investors would pay attention to the market capitalization, B/P, ROE, and total asset growth rate of each oil company when selecting stocks. This is because the U.S. economy was booming, unemployment was low, consumer confidence was high, oil demand was high, and therefore oil prices were high. In addition, companies in the oil industry were in good financial shape overall and the stock market was in healthy condition.

According to the chart in Table 1 of Description, the coefficient of $R_m - R_f$ is greater than 1, indicating that the share price fluctuations in the oil industry are in sync with the market, but the magnitude is greater; the coefficient of SMB is greater than 0, indicating that investors prefer oil companies with smaller market capitalization, which is because oil is a sunset industry and the share price of large companies is hardly volatile, while investors choose small companies, actually in exchange for a higher risk premium; the coefficient of HML is greater than 0, indicating that investors prefer oil companies in the high B/P group, indicating that the value of the equity of the company corresponding to the shares is higher than the share price, which means that the stock is undervalued [6]; RMW coefficient is less than 0, indicating that investors are more likely to choose oil companies with lower ROE, which is because low ROE indicates greater stock volatility. Especially in the oil industry, most oil companies have a high level of ROE and are high-quality companies, but the stocks of such companies tend to be more stable and difficult to make profits, so investors prefer to choose the stocks of oil companies with higher volatility; CMA number is less than 0, which indicates that investors prefer oil companies with higher total asset growth rate, i.e., investors pay attention to the rate of asset The speed of expansion of the operating scale of oil companies in a certain period.

Thus, for the period January 2, 2019 to March 12, 2020, the oil sector in the U.S. stock market fits the Fama-French five-factor model with all five factors significant due to the combination of a booming U.S. economy, high oil demand, and strong financial position of companies in the oil sector.

4.2 Before the successful development of the COVID-19 vaccine

Since the announcement of the COVID-19 outbreak in the U.S. on March 13, 2020, the oil industry group no longer fully fits the Fama-French five-factor model, and two factors, RMW and CMA , are not significant. This is because the outbreak of the COVID-19 epidemic led to extreme global economic instability, lower consumer confidence, lower oil demand, and lower oil prices. At the same time, the epidemic had a significant impact on the operations of companies in the oil industry, which led to a decline in the overall stock prices of the oil industry. As a result, during this period, stockholders stopped caring about the ROE and total asset growth rates of oil companies and focused more on the impact of the epidemic and the outlook for oil demand. Therefore, the stock prices of the oil industry group are no longer affected by the ROE and total asset growth rate under the impact of the COVID-19 epidemic, and the factors RMW and CMA are no longer significant.

Quantitative easing policies such as the massive, high-speed fiscal expansion implemented by the U.S. government during the COVID-19 pandemic, the overall expansion of fiscal bailouts, and the link between fiscal and monetary policies may have had an impact on the significance of the RMW and CMA factors. These policies were aimed at injecting liquidity into the financial system and supporting the economy during the crisis, which may have led to lower interest rates, higher asset prices and possibly influenced investor behavior.

Investors may be more concerned with short-term earnings than with long-term fundamentals such as ROE and total asset growth, as policies designed to support the economy may have created an environment of low interest rates and increased market optimism. This shift in investor behavior may have reduced the importance of the RMW and CMA factors, as investors may be less concerned with ROE and total asset growth of oil companies.

4.3 After the successful development of Pfizer vaccine

The introduction of the vaccine may have improved growth prospects and therefore increased investor interest in oil companies with more growth prospects, resulting in significant RMW and CMA factors.

On February 24, 2022, the Russia-Ukraine war officially breaks out. The outbreak of the Russian-Ukrainian war could bring about global economic uncertainty and affect market behavior. On March 16 of the same year, the Fed announced a 25 basis point interest rate hike, and in May the Fed raised rates by another 50 basis points in one go, while in June and July, the Fed raised rates by another two significant 75 basis points. On August 26, at the annual meeting of global central banks in Jackson Hole, Fed Chairman Powell emphasized the "no sacrifice to the economy to control inflation "The "strong" measures will continue to be taken to fight inflation [5]. Since then, the Fed has continued to march on the path of aggressive rate hikes. In the early hours of Thursday, September 22, Beijing time, the Fed raised interest rates again by 75 basis points, raising the target range for the policy rate federal funds rate to 3.00%-3.25%; the upper limit of the federal funds rate range - the excess reserve rate (IOER) was raised by 75 basis points, from 2.4% to 3.15 percent. On November 3, Beijing time, the Federal Reserve rate meeting announced a 75 basis point rate hike, raising the target range of the federal funds rate to 3.75%-4%. This is the Fed's sixth rate hike since 2022 and the fourth consecutive 75 basis point hike, the largest intensive rate hike since 1981 [7].

The Fed's rate hike was meant to curb inflation and was actually negative for the stock market. Also considering that oil is negatively correlated with the U.S. dollar, the strength of the dollar also brought about a decline in oil prices, and the oil industry as a whole was hit hard, with Brent crude oil futures in London falling from $139.13 to $87.25, an increase or decrease of -5.67, so investors

no longer pay attention to the size of the market capitalization of each oil company, leading to the insignificance of the SMB factor. Therefore, the combination of these factors may lead to market behavior inconsistent with the Fama-French five-factor model.

The main purpose of interest rate hikes is to curb inflation, i.e., to reduce inflationary pressures by using higher interest rates to reduce consumers' and businesses' willingness to borrow. However, interest rate hikes may also have certain effects on the economy, such as reducing liquidity and affecting stock markets and stock prices, thus impacting investors. The Fed's decision to raise interest rates may affect stock market sentiment. When the Fed raises interest rates, interest rates rise, which could potentially cause the stock market to move erratically, thus affecting the investment performance of various stocks.

And for RMW and CMA to be significant, this may be related to the company's profitability, financial position, etc. If the profitability and financial position of oil companies continue to be good, then the stocks of these companies may be favored by investors, which leads to RMW and CMA significant.

Regarding other related factors, from the perspective of the Russian-Ukrainian war, the instability brought by the war could affect the production and sales of the oil industry and test the company's financial performance even more, thus drawing investors' attention to RMW and CMA. In addition, the successful development and launch of the vaccine could bring about a recovery in the global economy, including the airline, hotel and restaurant industries, which are all major consumers of oil, thus favoring higher oil demand, but combined with the policy and political headwinds, investors need to look at RMW and CMA.

At this stage, the p-value of α is greater than 0.05 and α is significant, indicating anomalies in the five-factor model. This is due to the following reasons: changes in the market environment, such as the Russian-Ukrainian war and the success of the Pfizer vaccine development, may lead to market volatility, which may affect stock prices and company performance; investor behavior and confidence may also affect market performance, causing the model to not meet expectations; economic factors, such as interest rates, inflation and economic growth rates; and instability in the political environment, such as the Russian-Ukrainian war [8].

The combination of these factors may cause the U.S. oil sector to fall short of expectations and investors to consider additional factors when investing, resulting in anomalies in the five-factor model.

4.4 After the U.S. declared the end of the COVID-19 outbreak

After the end of the epidemic and the announcement of the end of the COVID-19 epidemic in the United States, there were some changes in the five-factor model of the U.S. oil industry. The factor RMW became insignificant, indicating that investors no longer pay attention to the ROE of U.S. oil companies. The insignificance of RMW may be due to the fact that investors are more sensitive to the rising cost of capital due to the expected increase in interest rates, which has lowered the ROE of most oil companies, and therefore no longer pay attention to RMW.

However, the SMB factor still remains insignificant, indicating that investors are still not concerned enough about the market value of oil companies after the end of the epidemic. This may be due to the fact that even after the end of the epidemic, the war between Russia and Ukraine continues, leading to an unstable international situation and economic situation, which affects investors' confidence in the oil market and makes them remain cautious. Together with the Federal

Reserve's interest rate hike policy, it has also had a negative impact on the market [8]. As a result, investors may no longer pay attention to the market capitalization of oil companies and the SMB factor remains insignificant.

5. Conclusion

This article employs the Fama-French 5-factor model to analyze the stock and market changes in the oil industry with the regression results based on the data of 4 periods in COVID-19 pandemic.

The significant changes of the five factors indicate that at different stages of the epidemic, investors will pay different attention to the US stock oil industry when making investment decisions. When a major public health event such as the COVID-19 epidemic occurs, a large part of investors will choose not to pay attention to the ROE and total asset growth rate of oil companies and may pay more attention to short-term benefits rather than long-term fundamentals. When there is good news in the market, such as the successful development of Pfizer's vaccine, but at the same time, bad events occur, such as the US dollar's interest rate hike and the war between Russia and Ukraine, after weighing the pros and cons, most investors will give up on the market value of oil companies but will refocus on ROE and total asset growth rate, the long-term fundamentals of enterprises. After the United States announced the end of the epidemic, the positive development of the stock market also brought about an increase in expected interest rates, which led to an increase in the cost of capital and a general decrease in the ROE of oil companies. Considering that the world situation is still tense and the interest rate hike cycle in the United States, investors still maintain a wait-and-see attitude towards the major companies in the oil industry, so they still do not pay attention to the market value.

Certainly, this paper still has limitations. This article does not fully analyze the changes in the oil industry in the U.S. stock market after the U.S. announced the end of the COVID-19 epidemic. Because the data collection only ends on November 30, 2022, it is difficult for this article to conduct further fitting and analysis based on the latest stock market data.

Therefore, this article suggests that investors should always pay attention to the occurrence and progress of events affecting oil prices and grasp the overall trend of the oil industry's stock prices. The investigation of relevant indicators of different companies should be selected according to the overall industry trend, and investment strategies should be adjusted in different periods.

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