Guo et al. found that measures, e.g., locking down cities and suspending work led to a recession in the real economy by affecting demand and supply, thereby straining liquidity in multinational financial markets, sharply falling asset prices, and increasing volatility [10]. The global spread of COVID-19 sends negative signals to financial markets, undermining investor confidence, further reducing stock prices and market efficiency [4], and adversely affecting liquidity, correlation and volatility [6]. As a once-in-a-century black swan event, the global spread and further deterioration of the COVID-19 epidemic has caused serious economic and social impacts. The US stock market was blown four times in March, and countries had to take blockade measures one after another to curb the spread of the epidemic. Subsequently, it was a severe shock to the economy as discussed detailly in Ref. [8]. The pandemic has already had a huge negative impact on the economy. The epidemic first hit the tertiary industry directly from the demand side. Among them, transportation, warehousing, wholesale and retail, tourism, accommodation, catering, offline entertainment, agriculture, forestry, fishery, animal husbandry and other industries are the most severely affected. In addition, due to the impact of the epidemic on the supply of elements needed to resume production, the flow of people, logistics, and capital has not been fully opened, and the industrial chain and supply chain cannot operate smoothly. The impact of the epidemic on the economy has already spread to the supply side, e.g., manufacturing, and real estate, import and export. Therefore, the impact of the epidemic on the industry is manifold.

Scholars conduct research on the impact of the market industry during the epidemic. Baig et al. investigated the impact of the COVID-19 pandemic on the microstructure of the U.S. stock market, explained liquidity and volatility dynamics through indices, and analyzed 48 Fama-French classified industries [11]. According to Ref. [1], the four-factor model fitting effect is more significant for large-scale, high book-to-market-cap ratio listed companies in the retail industry and Internet retail companies with a high book-to-market ratio. Besides, in the crisis market represented by the impact of the COVID-19 epidemic, the four-factor model passed the heterogeneity test, and the model fitting effect was better than that in the non-epidemic period [7].

The “black swan” has brought a greater impact on household consumption and enterprise production investment. In the face of the unknown epidemic and the uncertain impact, it is more likely to lead to pessimism and panic among investors. In turn, it triggers a stock market crash through investor sentiment. Therefore, how the stock market has been hit by the epidemic is worthy to in-depth study.

Based on the comparison of the CAPM model before and after the epidemic, this paper has a certain significance for the research on the return and risk volatility of stock portfolios in the US stock market and industry groupings. This paper examines the difference between before the COVID-19 and after. Specifically, this paper takes 2-3 stocks in each of the four US stock industries as samples, uses the regression analysis method to verify the effectiveness of the classical CAPM model before and after the COVID-19 period, and analyzes the difference between the actual rate of return and the expected equilibrium rate of return and its causes.

The rest part of the paper is organized as follows. The Sec. II will present the data and methodology. The Sec. III will present the findings and discuss them. The Sec. VI will draw the conclusions of this research.

Figure 1. Stock price history of Tesla.

2. METHODOLOGY

2.1. Data

The data about stock information in this article comes from the Yahoo database, and the stock return is calculated by obtaining the stock’s closing price. Data on risk-free rates and market rates are from Kenneth R. French's data. (http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html). In order to analyze the related industries of U.S. stocks in more detail, the daily data of 2-3 stocks in 4 industry categories are selected respectively. The industries and stocks selected in this paper are automobile making, bank, pharmaceutical and Internet e-commerce industries respectively. Automobile manufacturing: Tesla, General Motors (GM); Bank: Bank of America (BAC), Citigroup (C), Morgan Stanley (MS); Internet e-commerce; Amazon (AMZN), E-bay (ebay); Pharmaceutical: Pfizer (PFE), Moderna (MRNA). Considering that the COVID-19 epidemic caused large-scale transmission in the United States in March 2020, the data from March to December was selected as the data after the outbreak. In order to make a fair comparison between the pandemic period and the control period, the data of the same length of time (March 2019 to December 2019) was selected as a reference for the pre-epidemic comparison. This was carried out to reduce the impact of market anomalies, such as the January effect, or any other impact that may be related to a specific time period.

Figs. 1 and 2 show the price movements of TSLA and GM from 2018 to 2022. Seen from the results, the impact of the epidemic on the stock market is far-reaching, and the stock price fluctuates violently during the epidemic.

Figure 2. Stock price history of GM.

2.2. Model

The CAPM model is a model used to measure the relationship between risk and return. The CAPM model believes that risk can be eliminated by diversifying investment to eliminate unsystematic risk, while systematic risk can be obtained by obtaining a matching risk premium. The following is the formular of the CAPM model:

$$E(r_i) = R_f + \beta\left[E(R_m) - R_f\right] \quad (1)$$

where E(r_i) is the expected rate of return on asset i, R_f is the risk-free rate, β is the Beta coefficient, i.e., the systematic risk of asset i, E(R_m) is the expected market return of market m, E(R_m)-R_f is the market risk premium, which is the difference between the expected market return and the risk-free rate of return. The original CAPM model is an exactly linear model that predicts stock returns in advance. Therefore, the first step to test it is to transform the theoretical capital asset pricing model, into an ex post form that can use historical data, i.e., the model is transformed into a single linear regression model, and then the regression method is used to test whether the CAPM model is applied to the stock. Therefore, after a series of changes, we set the empirical model to be tested as:

$$R_{it} - R_{ft} = \alpha_i + \beta_i \left(R_{mt} - R_{ft}\right) + \varepsilon \quad (2)$$

Here, R_{it} stands for the expected return of the i^{th} stock at time t. The formular is as follows:

$$R_{it} = \frac{[(P_{it} - P_{it-1}) + D_{it}]}{P_{it-1}} \quad (3)$$

Here, R_{mt} represents the return of the stock market portfolio at time t. R_f stands for risk-free rate of return. In theory, the beta coefficient represents the risk premium of a stock or portfolio relative to the market, which reflects both systematic risk and market excess premium. This paper regresses the data before and after the epidemic, and compares the changes in the β coefficient.

3. Results & Discussion

3.1. Automobile Manufacturing

The sudden outbreak of the COVID-19 epidemic in many places around the world has brought a huge impact on the automobile industry. The global automobile industry, which is already in a downward channel, has been profoundly affected by the closure of factories, damaged operations, and blocked trade. Automobile manufacturing industry went from a beta of 1.639 in 2019 to 1.615 during the pandemic period. In 2019, if the market rose 1%, automobile manufacturing would rise 1.639% on average. During the pandemic, when the market rises 1%, automobile manufacturing rises by 1.615%. In the second model (After), the intercept term passed the test at the 10% significance level, which is 0.337%, and the sign is positive. According to the economic meaning represented, it can be seen that the stock's actual return is higher than the expected return,

i.e., the price of the stock is higher than its intrinsic value, and the price of the stock is expected to be lower.

From Table 1, the β coefficient represents the correlation between the return of an asset and the market portfolio, and the magnitude of the β coefficient reflects the sensitivity of the return of an asset to changes in market returns. The estimated value of the coefficient β is 1.615, which has passed the test at the 1%. If the β coefficient could pass the significance test, it means that the CAPM model is valid, otherwise, the CAPM model is invalid. Therefore, the empirical evidence for this stock shows that the CAPM model is effective in the post-COVID-19 period. Meanwhile, if the β coefficient is greater than 1 and the sign is positive, it can be seen that the return of the stock is positively correlated with the return of the market portfolio.

According to the results, during the epidemic, due to the government's closed management policy, the travel ratio was reduced. People working from home and telecommuting have reduced the demand for cars. In addition, as a result, the reduction in demand will have a huge impact on automakers.

TABLE 1. CAPM MODEL BASED ON AUTOMOBILE MANUFACTURING

	Before Ri (Rf)	After Ri (Rf)
MktRF	1.639 (0.177)	1.615(0.096)
Constants	0.013(0.109)	0.337(0.178)
N	408.000	410.000
r2	0.175	0.412
F	86.067	285.537
p	0.000	0.000

TABLE 2. CAPM MODEL BASED ON BANK

	Before Ri (Rf)	After Ri (Rf)
MktRF	1.754 (0.066)	1.807 (0.052)
Constants	0.008 (0.040)	-0.071(0.097)
N	612.000	615.000
r2	0.540	0.665
F	714.654	1214.276
p	0.000	0.000

3.2. Bank

In Table 2, bank went from a beta of 1.754 in 2019 to 1.807 during the pandemic period. In 2019, if the market rose 1%, Bank would rise 1.754% on average. Now, when the market rises 1%, Internet e-commerce rises by 1.807 %.

In this paper, the model regression goodness-of-fit R-square is chosen to represent the analytical ability of the model. The R2 during the epidemic is greater than the R2 before the epidemic, indicating that the model interpretability has improved. The estimated value of the coefficient β during the epidemic is 1.807, and it has passed the test at the 1%. If the β coefficient can pass the significance test, it means that the CAPM model is effective, otherwise, the CAPM model is Invalid. Therefore, through the empirical evidence of this stock, it can be seen that the CAPM model is effective in the late stage of COVID-19. If the beta coefficient is greater than 1 and the sign is positive, it can be seen that the return of the stock is positively correlated with the return of the market portfolio, and the systematic risk is greater than the risk of the market portfolio.

Finance is the bloodline of the real economy. During the COVID-19 outbreak, the banking industry would be the first to be affected. The prime reason for this is that financial services are, to some extent, the essential attributes of public goods. On the one hand, its much number of physical business premises distributed all over the country are the distribution center for the flow of people and passengers, and a large number of enterprises and residents need to go to its business premises to handle financial business, which intensifies the risk of epidemic spread. On the other hand, banks are out of risk control need, in the process of business, contracts and documents involving legal texts require the customer's handwritten signature, which inevitably leads to close contact between people. In addition, this process of business development will also increase the risk of the spread of the epidemic. The epidemic has created a good opportunity for big banks to integrate industries, penetrate regions, and further consolidate their scale advantages. Besides, banks are constantly moving to the mobile terminal, and technologies such as blockchain make the banking industry be more and more closed to the technology industry. Therefore, the broad customer base and number of customers will allow large banks to form a good self-reinforcing feedback chain. The network effect is obvious, which could be seen in the retail business of Bank of America as a clue.

3.3. Internet E-commerce

From a global perspective, cross-border e-commerce mainly emerged at the turn of the century. With Amazon and eBay landing in the European market in 1998 and 1999, respectively. As a new type of foreign trade, cross-border e-commerce has maintained rapid growth in recent years, and has become an important starting point for stabilizing foreign trade, stabilizing employment, and promoting the economy. Affected by the epidemic in overseas markets in 2020, the demand for a large number of anti-epidemic materials, home office supplies, pet supplies, etc. has surged, further stimulating the export of cross-border e-commerce.

In Table 3, the beta shifts are dramatic. For instance, Internet e-commerce went from a beta of 1.405 in 2019 sharply down to 0.716 during the pandemic period. In 2019, if the market rose 1%, Internet e-commerce would rise 1.405% on average. Now, when the market rises by 1%, Internet e-commerce rises by 0.716%.

The estimated value of the coefficient β is 0.716, and it has passed the test at the 1% significant level. According to the meaning of the β coefficient, if the β coefficient can pass the significance test, it means that the CAPM model is valid, otherwise, the CAPM model is invalid. Consequently, through the empirical evidence of this stock, it can be seen that the CAPM model is effective in the late stage of COVID-19. The beta coefficient of Internet e-commerce during the epidemic is less than 1 and is positive, indicating that there is a correlation between the change in the yield of Internet e-commerce and the change in the yield of the entire industrial market, and the change in the yield of Internet e-commerce is less than the rate of return of the entire market, the return risk is lower than the average risk level of the entire market.

Apparently, due to the impact of the COVID-19 epidemic, the overall global trade was sluggish, but the trend of digital transformation of trade represented by cross-border e-commerce became more and more obvious. At the beginning of the outbreak, residents' going out for shopping was seriously affected. The advantages of cross-border e-commerce bonded import have been fully utilized. After consumers place an order online, cross-border e-commerce bonded import can quickly deliver the purchased imported goods to consumers, reducing opportunities for consumers to contact offline and avoid the human-to-human transmission of the virus is also conducive to national epidemic prevention and control. The epidemic has made more backward countries in the cross-border e-commerce field attach great importance to this new type of trade. Owing to their differences in economic endowments and policy space from developed economies, some emerging economies have been severely hit by the epidemic. Therefore, they are paying more and more attention to the role of cross-border e-commerce, a new form of trade. The epidemic has made some countries with high levels of cross-border e-commerce pay more attention to global digital trade. Moreover, it has objectively driven the development and application of digital technology, allowing the world to see the important role the digital economy and digital trade play in responding to sudden global public health and security crises, thereby accelerating the transformation of cross-border e-commerce to global digital trade pace.

TABLE 3. CAPM MODEL BASED ON INTERNET E-COMMERCE

	Before Ri (Rf)	After Ri (Rf)
MktRF	1.405(0.083)	0.716(0.054)
Constants	-0.082(0.051)	0.119(0.101)
N	408.000	410.000
r2	0.414	0.300
F	286.779	175.142
p	0.000	0.000

TABLE 4. CAPM MODEL BASED ON PHARMACEUTICAL INDUSTRY

	Before Ri (Rf)	After Ri (Rf)
MktRF	1.064(0.214)	0.423(0.117)
Constants	-0.084(0.132)	0.461(0.219)
N	408.000	410.000
r2	0.058	0.031
F	24.846	13.000
p	0.000	0.000

3.4. Pharmaceutical Industry

During COVID-19, the pharmaceutical industry has also demonstrated its ability to deal with this large-scale health crisis. On November 9, 2020, Pfizer announced that the COVID-19 mRNA vaccine jointly developed with the German biotechnology company BioNTech can effectively prevent 90% of the disease. The COVID-19 virus infection has injected a booster into the global capital market.

The beta shifts are tremendous. As summarized in Table 4, pharmaceutical industry went from a beta of 1.064 in 2019 to 0.423 during the pandemic period. In 2019, if the market rose 1%, Pharmaceutical Industry would rise 1.064% on average. Now, when the market rises 1%, Pharmaceutical Industry rises by 0.423%. During the epidemic, the beta coefficient is less than 1 and is positive, indicating that there is a correlation between the change in the rate of return of the pharmaceutical industry and the change in the rate of return of the entire market. The return risk is lower than the average risk level of the whole market.

The outbreak of the epidemic has prompted people to further realize the importance of health, and the medical field will usher in explosive growth. There will be a blowout growth in the field of health care, elderly care, and health care. After the epidemic, the public has paid more attention to hygiene, medical care and health, which has created a good environment for medical-related enterprises to develop with high quality in the future. The pharmaceutical industry in the world's major capital markets is the main source of long-term stocks. With the outbreak of the COVID-19, companies (e.g., masks, ventilators, virus prevention and vaccine research and development) have performed well, which has also brought confidence to the social and financial markets.

3.5. Limitation

The limitations of this paper are that only 2-3 stocks were sampled in each industry instead of the whole stocks, i.e., the sample size was insufficient. Second, the CAPM model is not suitable for analyzing the expected stock returns of some industries after the epidemic. Further studies could focus on the improvements of the models, e.g., Fama-French multifactorial models.

4.Conclusion

In summary, this paper investigates the impact of COVID-19 on automobile making, bank, pharmaceutical and Internet e-commerce industries based on CAPM model. Specifically, it takes 2-3 stocks in each of the four US stock industries as samples, using the regression analysis method to verify the effectiveness of the classical CAPM model before and after the COVID-19 period. Specifically, the period from March 1 to December 31, 2019 was used as the pre-pandemic control. The period from March 1 to December 31, 2020 is used as a post-pandemic control, which makes the empirical analysis more comparative. According to the analysis, the beta value of bank increased before and after the epidemic. While Internet e-commerce, automobile manufacturing and pharmaceutical industries saw their betas fall. The limitation of this paper is that the sample size of the selected stocks is small, and the quantity of selected samples should be expanded. Second, the CAPM model is not suitable for analyzing the expected stock returns of some industries after the epidemic. In the future, further studies ought to explore the impacts using three-factor and five-factor models, which will provide more valuable information. Overall, these results shed light on guiding further studying focusing on CAPM model.

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