

Impact of COVID-19 on United States' Investors' Sentiment

Statistics 601 Final Submission of Group 5

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1 Report on the Model

1.1 Introduction

1.1.1 Background

COVID-19 has indirect and direct impacts on consumers' confidence: keeping consumers at home, weary of discretionary spending and negative sentiment about the future[3]. Yin's[6] research shows that People's death caused by COVID-19 reported in the social media result in the negative sentiment. That is to say, COVID-19 influences United States' investors' sentiment directly through the relevant data reports published daily, such as death and recover data. In this project, we attempt to explore how COVID-19 affects investors' sentiment.

Since sentiment is hard to quantify, and in order to measure investors' sentiment, we find Market liquidity could be used as a sentiment indicator[2]. In the U.S. stock market, Volatility Index(VIX) is the most common used factor to represent the market liquidity[5]. It is to warn the potential market risks, and is often used as an important basis for investors to increase or decrease positions. It is an indicator that reflects the price of portfolio insurance. When investor concerned about a potential drop in the stock market, the more investors demand the insurance, the higher the price. In short, the higher VIX is, investors have less confidence on stock market.

1.1.2 Statistical Question

The statistical question we prompt is that how COVID-19 affects Volatility Index(VIX) and could we build some linear regression models between VIX and all those factors we discussed above, including daily deaths and recovers data of COVID-19. At the same time, we will also consider the impact of the Federal Reserve's rescue measures against the epidemic.

1.2 Data Selection and Analysis

1.2.1 Data Selection

- VIX is the indicator of United States' investor's sentiment

VIX, computed on a real-time basis throughout each trading day, is a forward-looking index of the expected return volatility of the SP 500 index over the next 30 days. We collected VIX data from FRED Economic Data.

- The daily deaths and recovers are the indicators of COVID-19

COVID-19 affects the investors' sentiment and reflects those impacts in the stock market[1]. Deaths and recovers is the most statistically reliable and sensitive data and real-time update. We collected COVID-19 data, including date, total cases, deaths and recovers of COVID-19 in the United States, from Centers for Disease Control and Prevention and its time span is from 21, January, when the first case was diagnosed, to 31, November, the date of the last recover data we could obtain.

- Federal funds rate is the indicator of government action

We notice when facing the pressure caused by COVID-19 on the United States' stock market, the Federal Reserve also made moves to alleviate the situation, and the committee decided to reduce the target range of the federal funds rate to 0-0.25% on 3rd March and 16th March. The federal funds rate refers to the overnight lending rate between American commercial banks. It is the interest standard for commercial banks to lend excess reserves to other banks that are short of funds. The reduction of federal funds interest rate is the direct action to reduce the interest of savings, stimulate people to make other investments, relieve people's panic about investment. We introduce the federal fund rate to reflect the regulation of the United States' government on financial market and the collected data are from the Federal Reserve Board website.

- Data set limitations

The stock market only has data on trading days, but COVID-19 data statistics are calculated on natural days. At the beginning of the outbreak, we find that some data were illogical, for example, the cumulative number of recover cases dropped suddenly. Although this is the official data, there may be some outliers before mid-February because the statistical standards have not been determined, which might cause our model not as applicable in the first few days of the surge of COVID-19.

1.2.2 Data Description

As shown by the Figure 1, for VIX index, it increased to the highest and then fell back, but still higher than values before March. For deaths and recovers, they kept increasing at a relatively constant rate. In the early stages of the epidemic, the slope of deaths continued to rise, and then the growth slowed after May. Regarding the recovers, in the early stage of the COVID-19, the slope of recovers used to be very small. Later, with the improvement of medical treatment, the recovers rose quicker, especially in 27th July and 2nd October there were two jumps. We believe that these two jumps may be caused by changes in detection methods. For FRB rate, after reducing interest rates twice on 3th March and 16th March, the FRB rate remains in a low position to keep the market liquid.

Table 1: Variable Table

Variable	Description
DATE	From 27th July to 30th November
VIX	Volatility index of Chicago Board of Options Exchange
log death rate	$\log(\text{total deaths})/\log(\text{total cases})$ per day
log recover rate	$\log(\text{total recoveries})/\log(\text{total cases})$ per day
FRB rate	federal fund rate per day

1.2.3 Data Pre-processing

- Trading Day

Because VIX index only exists on trading days, we delete COVID-19 data on non-trading days to match VIX. The length of the dataset is 218 and all of them are continuous.

- Ratio.

The original data we have are the total number of cases, deaths and recovers. However we find that when the number of new diagnoses per day become larger, it makes no sense to discuss the total amount of daily deaths and recoveries because they are not sensitive enough. Therefore, we use the daily proportion of deaths and recoveries as proxies for negative and positive COVID-19 report, respectively.

- Logarithm

From Table 2, We notice that with the continuous development of the epidemic, the death rate gradually decreased to around 0.03 and the recover rate gradually increased to approximately 0.5, which leads to a 10-fold difference and cause disturbance to our model. After taking logarithm, we could see that data are more balanced.

Table 2: quantile of rates

	0%	25%	50%	75%	100%
death_rate	0	0.024	0.030	0.050	0.080
recover_rate	0	0.110	0.301	0.530	0.653
log_death_rate	0	0.745	0.776	0.789	0.803
log_recover_rate	0	0.775	0.919	0.960	0.973

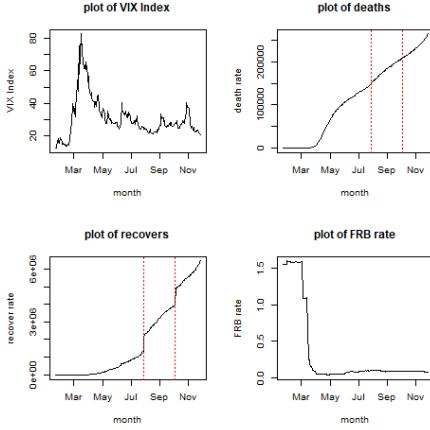


Figure 1: Data Trend

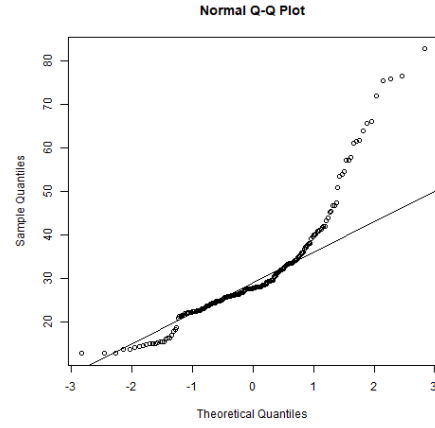


Figure 2: Q-Q Plot of VIX

1.3 Model

1.3.1 Model Introduction

In order to build the linear model, we assume that:

- Linearity. Since all the variables are continuous, we assume that response variable VIX influences variables through a linear function.
- Independence. Because we calculate death rate and recover rate by the proportion to the total cases and it is not in our model, the logarithm of death rate and recover rate are independent.
- Distribution. VIX follows a normal distribution with variance σ^2 . From Figure 2 we find that most of the VIX are normally distributed except some values that occur before mid-February.

In this part, we build a simple model and a full model respectively and in both models, ϵ is the random component and other parts are systematic components. Their null hypotheses as follows:

H_{10} : recover rate and death rate don't have impact on VIX

H_{20} : FRB rate doesn't have interaction effect towards recover rate and death rate

Model1:

$$VIX_t = \beta_0 + \beta_1 \log(\text{deathrate}_t) + \beta_2 \log(\text{recoveryrate}_t) + \epsilon_t \quad (1)$$

Model2:

$$VIX_t = \beta_0 + \beta_1 \log(\text{deathrate}_t) + \beta_2 \log(\text{recoveryrate}_t) + \beta_3 \log(\text{deathrate}_t) : \text{FRBrate}_t + \beta_4 \log(\text{recoveryrate}_t) : \text{FRBrate}_t + \epsilon_t \quad (2)$$

Model 1 only includes COVID-19 factors(log death rate and log recover rate). Actually, the government has taken actions to deal with the panic caused by COVID-19 to the stock market. In order to explore whether the effect of government intervention moderate investors' sentiment, we introduce federal fund rate(FRB rate). Because the government intervention of lowering FRB rate is caused by the COVID-19, we suspect that there are interaction effects between FRB rate, death rate and recover rate. Moreover, there is a strong multi-collinearity of COVID-19 and FRB rate and thus we only consider the interaction effects of FRB rate in the model.

1.3.2 Interpretation

Table 3: Model Regression Results

	<i>Dependent variable:</i>	
	VIX	
	(1)	(2)
log_death_rate	63.958*** (5.878)	170.762*** (10.491)
log_recover_rate	-58.353*** (5.687)	-134.881*** (8.314)
log_death_rate:FRB		-69.796*** (8.756)
log_recover_rate:FRB		87.805*** (7.231)
Constant	34.771*** (2.077)	18.982*** (2.052)
Observations	218	218
R ²	0.357	0.632
Adjusted R ²	0.351	0.625
Residual Std. Error	9.989 (df = 215)	7.599 (df = 213)
F Statistic	59.783*** (df = 2; 215)	91.286*** (df = 4; 213)
<i>Note:</i> *p<0.1; **p<0.05; ***p<0.01		

As illustrated in Table 3, the regression results are:

$$Model1 : VIX = 34.77 + 63.96\log(deathrate) - 58.35\log(recoverrate) \quad (3)$$

$$Model2 : VIX = 18.98 + 170.76\log(deathrate) - 134.88\log(recoverrate) - 69.80\log(deathrate) : FRBrate + 87.81\log(recoverrate) : FRBrate \quad (4)$$

Results of Model 1 show that we have enough evidence to reject the null hypothesis, and both of the log deaths rate and the log recover rate are significant. If log deaths rate increases by 0.1, VIX will increase by 6.40 and if log recover rate increases by 0.1, VIX will decrease by 5.84, which confirms the guess that deaths of COVID-19 would lose confidence of investors while recoveries would give investors confidence about the stock market.

The results of Model 2 are reasonable and all variables are significant, we can reject the null hypothesis and conclude that FRB rate moderates the log death rate and log recover rate. Similar to model 1, log death rate and log recover rate have stimulative and alleviative effects on investors' confidence respectively. If log death rate increases by 0.1, VIX increases by 17.08 and if log recover rate increases by 0.1, VIX decreases by 13.49. As for the interaction effect, FRB rate plays a moderating role in the model owing that if log death rate:FRB rate increase by 0.1, VIX decrease by 6.98 while if log recover rate:FRB rate increases by 0.1, VIX increases by 8.78. After comparing the two coefficients, it is clear that the impact of FRB rate adjustment is smaller when it comes to investors' falling confidence of log death rate.

From Figure 3 full model diagnostic, we could see that residuals distribute randomly on both sides of fitted values and time plots. In normal Q-Q plot, most of the residuals are approximately in a line but their distribution are slightly thicker than normal distribution on both sides because residuals on both ends are higher. This may be caused by the inaccuracy of data before mid-February.

In conclusion, from both the simple and full models, COVID-19 affects the investors' sentiment on recoveries alleviating and deaths aggravating it. Additionally, government intervention works on moderating effects of COVID-19 on sentiment.

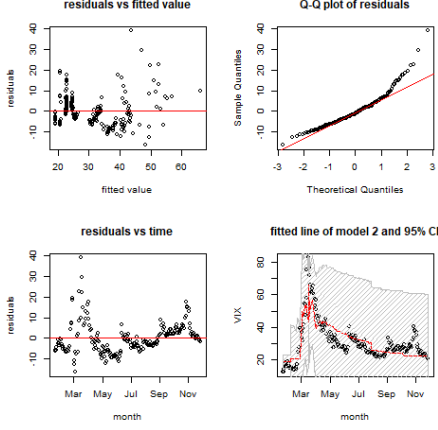


Figure 3: Full Model Diagnostic

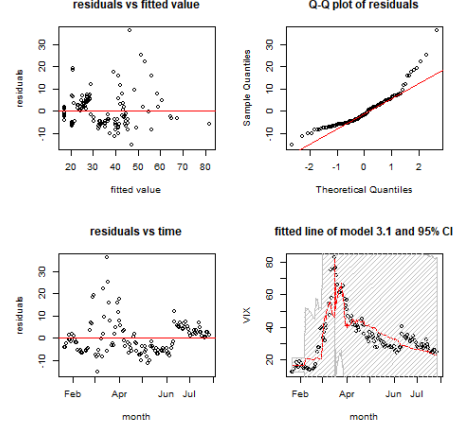


Figure 4: Segmented Model Diagnostic

1.3.3 Segmented Model

When inspecting the data, we find that there are two significant growth points of total recoveries respectively in 27th July and 2nd October, which are marked in Figure 1. Besides, after we elongate our data to from April, 2020 to November, 2020, the above full model doesn't fit as well as it did in our secondary report since R^2 decrease by 0.1.

Therefore, we suggest that the full model might behave differently in different stages of the pandemic. To solve the above two problems, we segment the model into three phases according to the two growth point and re-fit model 2.

1.3.4 Segmented Model Interpretation

Table 4 shows that phase 1 and phase 3 have similar results to the full model, that is if log death rate increases by 0.1, VIX will increase 25.70 and 7.93 respectively and if log recover rate increases by 0.1, VIX will decrease by 21.36 and 11.27 respectively. When considering FRB rate in phase 1, if log death rate:FRB and log recover rate:FRB increase by 0.1, VIX will decrease by 13.03 and increase by 14.07 respectively while in phase 3, FRB rate shows little interaction effect. However in phase 2, although the results are significant, they are in fact unreasonable.

Individually, phase 1 is considered the best fitted phase with the highest R^2 and relatively accurate results. A possible interpretation is that in the early stages of the epidemic, investors' sentiments are more sensitive to external factors.

However, VIX experienced up and down in early September due to the plunge in US technology stocks rather than the COVID-19 according to CNBC news[4], which might be an important reason for the comparatively odd results in phase 2.

During phase 3, the FRB rate was stable around 0.05, which could be considered as a constant in the model and therefore its interaction could hardly moderate the pandemic effects. Moreover, it is noticeable that in this period, log death rate impacts VIX significantly smaller than log recover rate. We conclude that the pandemic is in the phase of normalization and compared to the early stage, COVID-19 has much smaller effects on VIX.

Figure 4 is the model diagnostic of segmented model of phase 1. The residuals are randomly distributed and approximately follow a normal distribution. As well as that the estimated values are close to real VIX value. Compared to Figure 3, fitted values are closer to actual values in Figure 4.

To sum up, model behaves differently in the three phases. In the early stage of the pandemic, the model fits well and we consider that COVID-19 affects investors' sentiment with government intervention significantly moderate this effect. In the second stage, due to the fluctuation of VIX and the stable

trend of COVID-19 and FRB data, results are opposite from that of phase 1 and 3. During the last stage, both the pandemic and government intervention have less or do not have effects on investors' sentiment due to the normalization of the pandemic.

Table 4: Segmented Model Regression Results

	<i>Dependent variable:</i>		
	VIX		
	(1)	(2)	(3)
log_death_rate	256.968*** (16.440)	-7,234.755** (3,381.391)	79.311*** (21.677)
log_recover_rate	-213.554*** (14.224)	7,803.378*** (2,470.097)	-112.739*** (11.532)
log_death_rate:FRB	-130.290*** (12.540)	87,207.170** (33,663.500)	-25.547* (13.293)
log_recover_rate:FRB	140.712*** (10.647)	-70,688.410** (27,342.570)	-4.484 (18.693)
Constant	17.004*** (2.127)	-1,833.999*** (578.731)	72.520*** (8.750)
Observations	131	48	166
R ²	0.734	0.647	0.723
Adjusted R ²	0.726	0.614	0.717
Residual Std. Error	7.808 (df = 126)	1.739 (df = 43)	6.968 (df = 161)
F Statistic	87.106*** (df = 4; 126)	19.722*** (df = 4; 43)	105.278*** (df = 4; 161)

Note:

*p<0.1; **p<0.05; ***p<0.01

1.4 Criticism

We can see that FRB rate was at a very low value in the last period, which indicates that the liquidity of the market has been almost completely released. With the development of the epidemic, there will be more controlling measures to alleviate the impact of COVID-19 on investors' sentiment, such as vaccines. Moreover, the information of the investors' sentiment may not be fully represented by VIX.

At present, we use a linear model, which is the most suitable model within current knowledge, but after more learning, there might be other nonlinear models that can better fit the question.

1.5 Conclusion

Our model is more applicable in the early stage, that is, in the initial stage of the outbreak, investors' sentiment is more sensitive to the changes of the epidemic situation, and the government's actions to release market liquidity for COVID-19 are also effective. Nevertheless, with the development of the COVID-19, people gradually accept the status under the epidemic situation, and the fluctuation of the epidemic situation no longer has great impacts on investment sentiment.

After the long period of the spread of COVID-19, people get more insensitive to those daily report statistics, such as death cases and recover cases, and other social elements should be take into consideration for the change of VIX. For instance, the overall social situation under the epidemic situation is unstable for the United States, since this year is the election year. Since September, the presidential election began to affect investors' sentiment. Also, the epidemic related events, such as vaccines will continue to affect investment sentiment. Moreover, when FRB rate is reduced to almost zero, government might need to consider novel actions to moderate the COVID-19 effect on investors' sentiment. In conclusion, the most fundamental method to reduce the investors' panic sentiment is to control the spread of the COVID-19.

References

- [1] S. Baek, S. K. Mohanty, and M. Glambosky. Covid-19 and stock market volatility: An industry level analysis. *Finance Research Letters*, page 101748, 2020.
- [2] M. Baker and J. C. Stein. Market liquidity as a sentiment indicator. *Journal of Financial Markets*, 7(3):271–299, 2004.
- [3] P. Carlsson-Szlezak, M. Reeves, and P. Swartz. What coronavirus could mean for the global economy. *Harvard Business Review*, 3, 2020.
- [4] Jbursz. Big tech stocks close out a 'nightmare' september, Oct 2020.
- [5] R. E. Whaley. Understanding the vix. *The Journal of Portfolio Management*, 35(3):98–105, 2009.
- [6] H. Yin, S. Yang, and J. Li. Detecting topic and sentiment dynamics due to covid-19 pandemic using social media. *arXiv preprint arXiv:2007.02304*, 2020.