

Investigating COVID-19 Influence on the VIX Index through ARIMA Model Predictions.

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Abstract. The COVID-19 pandemic has impacted the global economy and stock markets, raising concerns and pessimistic emotions in the public. These public emotions would respond to the pandemic in the stock market, whereas the VIX index is a reflection of these emotions. This study utilizes ARIMA models to forecast the VIX index after the outbreak of COVID-19 based on the data before the pandemic and compares the predicted and actual values. The result shows a remarkable gap between the trained prediction and the actual VIX index after COVID-19, which indicates that any large-scale pandemic would incur an increased pessimistic expectation on the stock market in a short period. It would be wise for individual investors to change their portfolio into a conservative setup at the onset of any global crisis and consider investing in the VIX index. It would be reasonable for an enterprise to prepare some precautions like building up a business related to the crisis. For the government, it would be essential to predict the onset of any crisis and be prepared for the potential dramatic decreases in stock markets and the general economy.

Keywords: COVID-19 pandemic, the VIX index, ARIMA.

1. Introduction

COVID-19 outbreak, which started in December 2019 and rapidly spread globally throughout 2020, has had a profound and multifaceted impact on the word economy and stock markets, as well as the public health and the living patterns of billions people. Among all of the aftermath, one of the most significant influences is on the global financial market. The United States (U.S.), one of the countries with the highest mortality caused by COVID-19, logged their lowest stock price since the 2008 financial crisis in February 2020.[1]

COVID-19 pandemic had a severe effect on the general economy. As Li et al. conclude, the U.S. GDP decline at the highest annual rate after the great depression, which is about 32.9%.[2] The unemployment rate rose above 14% in April 2020. The industrial production index also received a dramatic drop down, plummeted from 109.2 to 91.3 within three months after the outbreak of COVID-19 in the U.S., with an average total decline of 98.9, which is more significant compared to the 2009 financial crisis. Real personal consumption expenditure has a sharp decline on the average of 12489.3 due to the closure of businesses during COVID-19. [2]

Fernandes studied how COVID-19 affected the global economy until late March 2020. The author observed a dramatic drop in the global stock market: most stock markets recorded their historical greatest one-day fall, and some famous companies' stock prices collapsed by more than 80% within two weeks. The United States had the worst fall, over 25% in stock markets, while the British had a decline over 35. Fernandes highlighted an underestimation of the pandemic outbreak impact on stock markets, which could not use other pandemics like SARS or the 2008 crisis to compare. [3]

The influence of COVID-19 on the stock market was dramatic in a short term, led by the raising uncertainty and fear of the public from the pandemic. The sharp declines in the stock prices reflected the market participants' concerns due to the rapid increase in mortality inside the states. Market participants' reaction to the crisis increased the volatility and a significant rise in the Volatility Index (VIX). The Volatility Index is a real-time index reflecting market participants' expectations on the recent changes in the S&P 500 Index. Elevated VIX levels correspond to the increased fear among investors, suggesting low confidence in the market's stability. During the COVID-19 period, the VIX reached an incredible level not seen after the financial crisis of 2008.

Many researchers predicted that the COVID-19 outbreak would significantly impact the stock market and VIX index. Albulescu [4] found a positive influence of the death ratio on the VIX, which had a stronger effect outside China.

However, some markets still thrived during the pandemic. Desjardins discovered that stocks related with internet products, outdoor delivery, health, and virtual financial benefited from the crisis, showed a 12.7% bump in price on average within a month after the pandemic started in U.S. these thriving stocks inference that the once the market participants habituated the pandemic, the general fear toward the stock markets should be mediated and the VIX index would have plummeted.[5]

Thus, a close inspection of the changes in the VIX index during the pandemic would be important to investigate since it is necessary to understand the relationship between the COVID-19's impact on the stock markets and on the public. Albulescu provides concrete evidence that COVID-19 positively impacts financial volatility through an ordinary least square approach.[6]

The rest parts of the article include section 2 discussing the research design, section 3 the results interpretation, and section 4 conclusion.

2. Research Design

2.1. Data Source

This paper adopts the VIX index in Investing.com, which is a financial platform that provides data, news, and analysis on world stock markets. The closing prices for the VIX index were selected from January 4, 2010, to February 1 2024, including about ten years of data before the pandemic started, which are treated as the training set to fit the model. The date of COVID-19 outbreak in the U.S., January 20, 2020, was set as t_0 since it is the date CDC recorded as the first case of COVID-19 in the United States. The data were collected in daily and weekly formats, and two ARIMA models were fitted for each specifically.

2.2. ARIMA Model

From equation (1) above, $c + \sum_{i=1}^p \phi_i y_{t-i}$ represents the AR(p) model, and the rest of the equation is the MA(q) model. AR(p) model estimates the future value by applying the past log VIX index from January 2010 to January 2022, while the MA(q) forecasts by adding an error term.

$$y_t' = c + \phi_1 y_{t-1} + \dots + \phi_p y_{t-p} + \theta_1 \varepsilon_{t-1} + \dots + \theta_q \varepsilon_{t-q} + \varepsilon_t = c + \sum_{i=1}^p \phi_i y_{t-i} + \varepsilon + \sum_{k=1}^q \theta_k \varepsilon_{t-k} \quad (1)$$

2.3. Weak Stationary Test

Before starting the model construction, a weak stationary test toward the log VIX index must be completed to check whether the dataset is stationary. After entering the data into STATA and performing the weak stationary test, the p-value (Table 1) for the log VIX index is 0, which is less than 0.01, suggesting that the data is stationary.

Table 1 Weak stationarity test for log VIX and log return

	t	p
Daily		
Ln VIX	-7.216	0.000
1st order difference	-38.530	0.000
Weekly		
Ln VIX	-5.555	0.000
1st order difference	-19.542	0.000
2nd order difference	-29.389	0.000

3. Results

3.1. ARIMA specification

The first step is necessary to check the PACF and ACF plots for the VIX log return, shown as Figure 1 below.

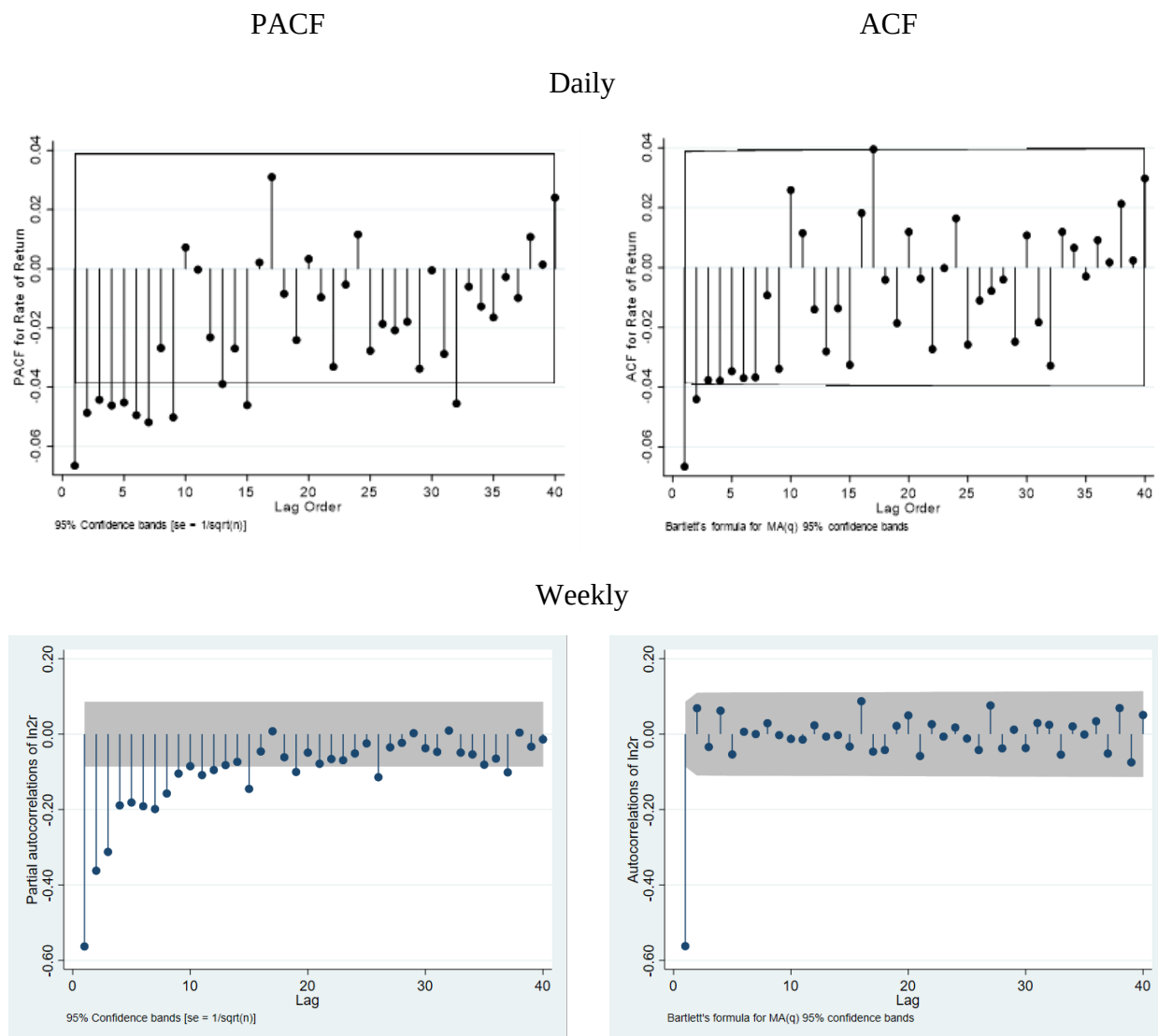


Figure 1 ARMA(p, q) identification PACF and ACF

Note: The Y-axis represents the dependent variable: PACF, and ACF of the log return on the 1st difference daily and 2nd difference weekly VIX index. The X-axis shows the lag order and 95% confidence intervals for AR(p) and MA(q) are bounded by $y = \pm 2$ sd.

Photo credit: Original

From the PACF and ACF plots of daily VIX index data, the lag order of 9 should be chosen for the AR model, and the lag order of 2 should be chosen for the MA model, thus the ARIMA model for the daily data would be ARIMA (9,1,2).

From the PACF and ACF plots of the weekly VIX index data, the lag order of 9 should be chosen for the AR model, and the lag order of 1 should be chosen for the MA model. Since the PACF and ACF plots consider the 2nd difference of log VIX index in weekly data, the ARIMA model for the weekly data would be ARIMA (9,2,1)

After fitting the two ARIMA models, it is necessary to apply a residual test on these two models to check whether the autocorrelations come from a white noise series. A portmanteau test is applied, and the result is shown in Table 2.

Table 2 Residual test for ARIMA models

Model	Portmanteau (Q) statistic	Prob > chi2
Daily-ARIMA (9,1,2)	45.4998	0.2538
Weekly-ARIMA (9,2,1)	31.4522	0.8309

The p-value for Daily-ARIMA (9,1,2) greater than 0.05 indicates that the autocorrelations in the model do not come from a white noise series, which means this model is a good fit. Similarly, for Weekly-ARIMA(9,2,1), the p-value is significantly large suggesting that this model fitted the data well.

3.2. Prediction Results

The Daily-ARIMA (9,1,2) is then used to predict the VIX index after January 20, 2020.

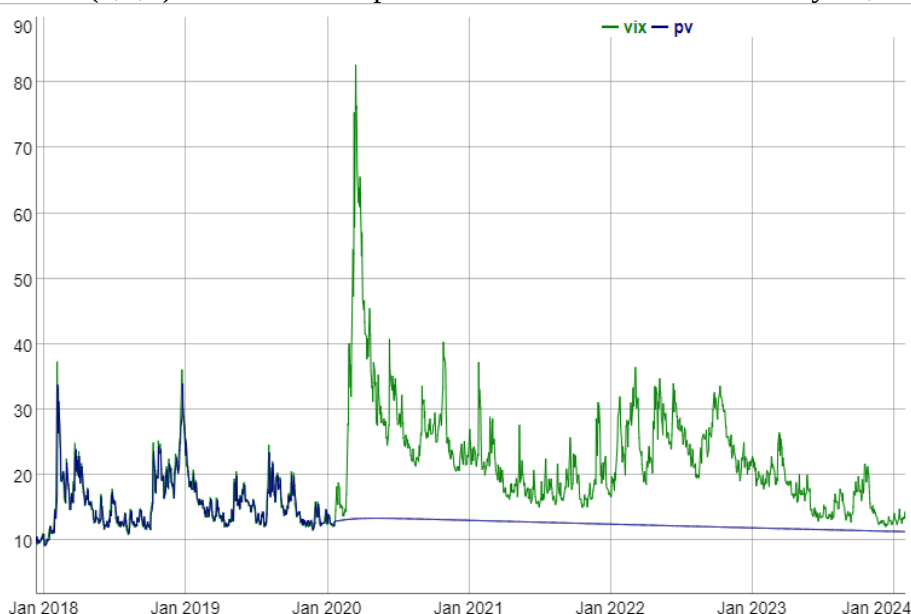


Figure 2 Actual value and predicted value, daily model

Photo credit: Original

Table 3 presents the results of the Daily-ARIMA (9,1,2) prediction compared to the actual values of the VIX index within two weeks after the outbreak of the pandemic in the U.S. Before the t_0 date, which is January 20, 2020, the model indicates a high level of accuracy with the largest percentage difference of 5.38% and the lowest percentage difference of 0.01%. However, the level of accuracy dropped extremely after the t_0 date, with the largest percentage difference of 44.97% and the lowest percentage difference of 12.19%.

Table 3 Actual value and predicted value, Daily-ARIMA (9,1,2)

	Actual VIX	Predicted VIX	Difference	Difference (%)
2020-01-10	12.56	12.6876	-0.1276	-1%
2020-01-13	12.32	12.62784	-0.30784	-2.44%
2020-01-14	12.39	12.37625	0.01375	0.01%
2020-01-15	12.42	12.49895	-0.07695	-0.06%
2020-01-16	12.32	12.4986	-0.1786	-1.43%
2020-01-17	12.1	12.42861	-0.32861	-2.64%
2020-01-21	12.85	12.19411	0.65589	5.38%
2020-01-22	12.91	12.85414	0.05586	0.04%
2020-01-23	12.98	12.91723	0.06277	0.05%
2020-01-24	14.56	12.977938	1.582062	12.19%
2020-01-27	18.23	12.980201	5.249799	40.44%
2020-01-28	16.28	12.984094	3.295906	25.38%
2020-01-29	16.39	12.981373	3.408627	26.26%
2020-01-30	15.49	12.969028	2.520972	19.44%
2020-01-31	18.84	12.995853	5.844147	44.97%
2020-02-03	17.97	13.007382	4.962618	38.15%
2020-02-04	16.05	13.033852	3.016148	23.14%
2020-02-05	15.15	13.045725	2.104275	16.13%

Similar patterns could be found in the prediction using the Weekly-ARIMA (9,2,1) model. Table 4 below compares the prediction of Weekly-ARIMA (9,2,1) and the actual VIX index within 2 months after the pandemic outbreak. Before the outbreak, the percentage differences between the predicted values and actual values are under 20%, the smallest difference percentage is at -0.03%. However, after the outbreak, the percentage difference increased dramatically after 1 month, reaching about 193.56% on February 23, 2020. The highest difference percentage occurred on March 15, 2020, with 383.96% above the predicted values.

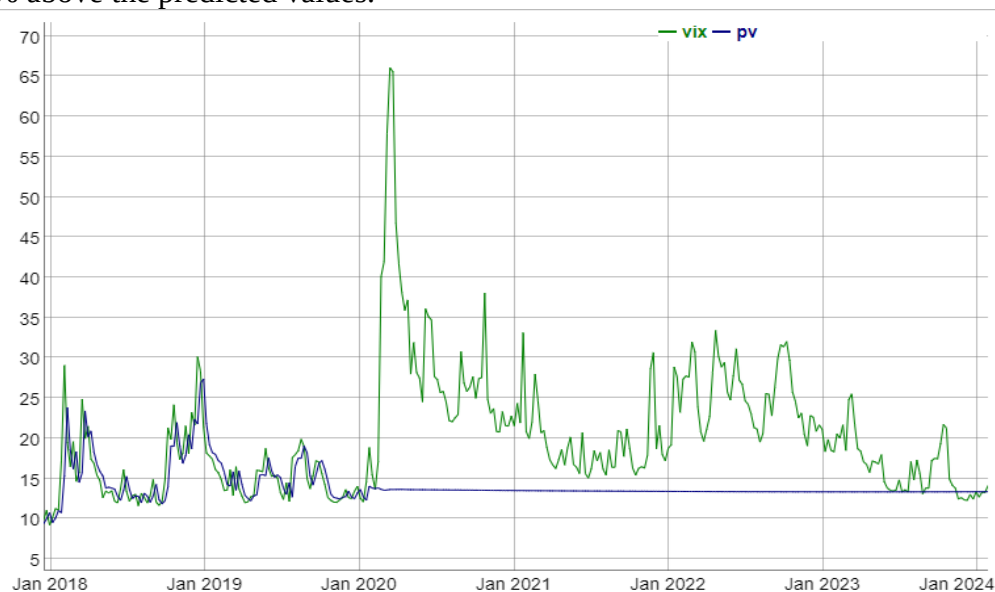


Figure 3 Actual value and predicted value, weekly model

Photo credit: Original

The time series plot makes the differences between predicted and actual values more obvious. Figure 2 and Figure 3 show the time series plots of the predicted and actual values for the Daily-

ARIMA (9,1,2) model and the Weekly-ARIMA (9,2,1) model. The predicted values(pv) in both Figure 2 and Figure 3 show relatively stable trends after the pandemic, whereas the actual VIX index values(vix) rapidly increased to the peaks on March 15, 2020, then dramatically plummeted. The vix kept decreasing, and the recent data are closer to the pv than previous data.

Table 4 Actual value and predicted value, Weekly-ARIMA (9,2,1)

	Actual VIX	Predicted VIX	Difference	Difference (%)
2019-11-24	12.62	12.65829	-0.003829	-0.03%
2019-12-01	13.62	12.75861	0.86139	6.75%
2019-12-08	12.63	13.4159	-0.7859	-5.86%
2019-12-15	12.51	12.70686	-0.19686	-1.55%
2019-12-22	13.43	12.49859	0.93141	7.45%
2019-12-29	14.02	13.18825	0.83175	6.31%
2020-01-05	12.56	13.64245	-1.08245	-7.93%
2020-01-12	12.1	12.73098	-0.63098	-4.96%
2020-01-19	14.56	12.31808	2.24192	18.2%
2020-01-26	18.84	14.051857	4.788143	34.07%
2020-02-02	15.47	13.814251	1.655749	11.99%
2020-02-09	13.68	13.743163	-0.063163	-0.46%
2020-02-16	17.08	13.837798	3.242202	23.43%
2020-02-23	40.11	13.6633	26.4467	193.56%
2020-03-01	41.94	13.551121	28.388879	209.49%
2020-03-08	57.83	13.5666	44.2634	326.27%
2020-03-15	66.04	13.645635	52.394365	383.96%
2020-03-22	65.54	13.631441	51.908559	380.80%

In general, the VIX index had a sharp climb after a short period, then dramatically declined as the stock participants habituated to the pandemic environment. Baek et al. provide a similar result through an MS-AR (1) model to investigate the changes in U.S. stock market volatility with COVID-19, and the result indicates COVID-19 would significantly cause an increase in the total risk of the U.S. stock market.[7]

Two other studies also confirm the result of this study from other perspectives. Grima et al. utilize the VAR model and Johansen and Juselius [8] method to test whether the relationships between COVID-19 bad news (cases and deaths), VIX index, and world stock market change.[9] Grima's result shows that A 1% increase in COVID-19 cases would lead the VIX index raising by 32.5%, but a 1% increase in COVID-19 deaths brings a decrease of 33.01%. This difference could be explained by the delay in counting the death cases, which could hint that people are more used to the situation during the time delay. Cheng et al. analyze the connection among stock markets through high dimensional VAR model with LASSO penalty during COVID-19 period.[10] Their results show that China's stock market disconnected from other stock markets due to the early lockdown. China still experienced a peak of the VIX index after the outbreak of COVID-19 and then quickly decreased, similar to other countries' stock markets.

4. Conclusion

This investigation has provided an in-depth analysis of how COVID-19 affected the VIX index, utilizing ARIMA models for forecasting the market's movement during this pandemic period. The COVID-19 pandemic raised public concerns and nervous emotions, which led to high volatility and pessimistic expectations toward the stock market. The reflection of these expectations is the

fluctuations in the VIX index. Previous literature indicates that the global crisis would lead to dramatic raise in the VIX index according to the severity of the crisis. But the crisis would also provide an environment for some companies or industries to thrive, such as Zoom. Thus, understanding the important pattern to estimate the scale of the pandemic influences on the stock market is crucial for preparation for the next pandemic.

This research provides the results of the forecasts from the ARIMA models toward the VIX index, selecting the VIX index before the pandemic as the training set and comparing the differences between the prediction of the VIX index and the actual VIX index. The dramatic changes in differences within three months provide us with knowledge about how rapidly the stock market would respond to the global pandemic. Once people got used to life after the pandemic, the concerns and pessimistic emotions toward the stock market would disappear, causing the VIX index to return to the level before the pandemic at an incredible rate.

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