

Impacts of the Interest Rate Increases on the US Technology Industry: Time Series Evidence

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Abstract. The interest rate increases by the United States Federal Reserve might have some impacts on the technology industry. This paper intends to find out how the stock prices under the monetary policies compare to the ones without the policies in the time span of a few days, weeks, and months. The prices that would have occurred without the policies are predicted using the ARIMA model. It is found that the technology stock price is approximately a quarter lower than the predicted price in the time span of a few months after the initial interest rate rise. There is a clear decreasing trend in the time span of a few weeks, though there is no significant impact on the stock price in the following few days after the interest rate rise. This paper innovates by comparing the effects of different time spans, which are quite different in terms of the scale of the effects. Using the findings, the suggestions for investors are that one should prepare themselves for a significant drop in the technology industry stock price in the long-term when there are similar policies, but should not panic in the short-term when the market has not reacted efficiently.

Keywords: Interest rate increase, technology industry, stock price, different time span.

1. Introduction

It is common that some government policies aimed at the whole economy will impact certain industries harder than others. Monetary policies, such as increasing or decreasing the money supply and adjusting the interest rate, are ways governments can use to influence the aggregate economy. The methods used to analyze the effects of a monetary policy in history usually concern the relationship between a variable and a macroeconomic time series [1].

In this paper, the macroeconomic indicator is the stock price of Dow Jones Technology, which can reflect the state of the technology industry to a large extent.

There have been done many pieces of research on the impacts of an increase in interest rates on the local stock market. According to different schools of macroeconomic thought, there is always disagreement on how large an effect monetary policy will be in stimulating the economy and why it might be so [2]. However, the consensus is that a higher interest rate should be imposed on an overheating economy, which ought to result in less production and inflation. Studies based on empirical data, like this one and many more, are capable of shedding some light on this debated field. A study concerning various developing and developed economies indicates that the stock price has a strong negative correlation with the interest rate in all countries included [3]. In contrast, only occasional casual relationships between the closing stock prices in Hong Kong and the interest rate (denoted by the Hong Kong Interbank Offered Rate) have been verified using the Granger causality test, and evidence is not sufficient to show that there is a negative relationship between the stock price and the interest rate [4]. But the lack of casual relationships might have resulted from policy reactions to the over-subscription of newly issued shares. The general stock market in Hong Kong has been found to adjust efficiently to the changes in the macroeconomic variable in this study.

These studies mainly focus on the general stock market, which contains many industries nationwide. This paper, however, focuses on one, the technology industry, in order to give more detailed results and provide specific suggestions to policymakers and investors in the US and abroad. It examines the effects of an increase in interest rates by the US federal reserve on the technology industry of the US. The American technology industry is one of the most advanced ones around the globe, attracting the attention of many investors. The performance of tech giants like Apple and

Google is constantly put on the front pages of financial websites. Despite relying heavily on scientific innovations, the industry's prosperity also is influenced by macroeconomic factors, such as the interest rate, as this paper is about to demonstrate. The US federal reserve increased its interest rates on March 16, 2022, in the hope of tackling the issue of ongoing higher-than-targeted inflation in the economy [5]. Eight interest rate increases have taken place since then, possibly impacting the technology industry. This paper uses the Dow Jones Technology stock price data before the interest rate increase to generate a model to predict the stock price which would have occurred without the monetary policy. First, the price data is processed into until the results are tested to be weak stationary under the Augmented Dickey-Fuller Test. After that, the method used to construct the model is the Autoregressive Integrated Moving Average (ARIMA), which is commonly used to predict future economic variables according to past information, it compares the theoretical prediction and the real data to arrive at a conclusion on how the industry was affected. Moreover, the analysis is divided into daily, weekly, and monthly closing prices to give an analysis of the market reaction on different time spans.

2. Research Design

2.1. Source of Data

The variable used to indicate the overall performance of the US technology industry in this paper is the Dow Jones Technology stock price on the New York Stock Exchange. The data are downloaded from investing.com [6], which is a reliable website where investors can find search for historical and current market information. The data used in this paper range from May 17, 2010, to July 06, 2022. The data before 2009 are avoided because the financial crisis in the US caused a plunge the stock prices, including the technology industry's stock price [7]. Also, the daily, weekly, monthly data are downloaded.

2.2. Weak Stationarity

In this section, the logarithm of the price of stocks plus one is used in order to eliminate the heteroscedasticity of the data. The equation is shown as follows:

$$\ln.close = \ln(close\ price + 1) \quad (1)$$

The Augmented Dickey-Fuller Unit Root Test is used to verify whether the time series data are weak stationary [8]. The null hypothesis is that the variable contains a unit root, and the alternative hypothesis is that a stationary process generates the variable. The variable for analysis has to be stationary in order to perform the ARIMA modeling. The p-value obtained from the test is 0.3109, indicating that the null hypothesis cannot be rejected at a 1% significance level. There is not sufficient evidence to show that the daily $\ln.close$ is weak stationary. Thus, the first-order difference for $\ln.close$ is used, which can be seen as the return of the stock price. The first-order difference for daily $\ln.close$ is obtained by:

$$\ln.close.r = \ln.close.r_t - \ln.close.r_{t-1} \quad (2)$$

$$d2.\ln.p = \ln.close.r_t - \ln.close.r_{t-1} \quad (3)$$

The same test for stationarity is conducted. The p-value for the results is 0.0000, meaning that the null hypothesis can be rejected and arrive at the conclusion that the daily $\ln.close.r$ is weak stationary. Similar processes for the weekly and monthly stock prices are carried out. All of the results are shown in Table 1. It is worth noting that the second-order difference for the monthly prices is used. It is not because of the failure to reject the null hypothesis for the first-order difference. It is due to the lack of significant coefficients for the ARIMA model for the first-order difference. The formula for obtaining the second-order difference, $d2.\ln.p$ is as shown:

Table 1. Weak stationarity test

		t	p
	Daily		
Raw		-2.535	0.3109
1st order difference		-39.530	0.0000
	Weekly		
Raw		-2.441	0.3581
1st order difference		-18.204	0.0000
	Monthly		
Raw		-1.991	0.6066
1st order difference		-10.259	0.0000
2nd order difference		-15.502	0.0000

2.3. The ARIMA Model

After ensuring that the variables analyzed are weak stationary, ARIMA is used to construct a model to predict the prices that would have been without the spike in interest rate based on past prices. The three ARIMA models used for the daily, weekly, and monthly data can each be denoted as ARIMA (p, d, q). The number p represents the order used in the autoregressive (AR) part in ARIMA, indicating the number of prior values, called lags, the current data seems to be regressed on. AR (p) can be expressed as:

$$DJI_t = \phi_0 + \phi_1 DJI_{t-1} + \phi_2 DJI_{t-2} + \dots + \phi_p DJI_{t-p} + a_t \quad (4)$$

With ϕ_p being the coefficients for the lags and a_t being the error. For example, if the p is 2, then it indicates that the evolving value is regressed on its own two prior values. Exactly how much the order should be is determined using the Partial Autocorrelation Function (PACF). If the PACF of a certain order of the lag is outside of a certain threshold, then it indicates that the current value is significant, or likely to be related to that order of lag. If not, then it is likely that the current value is independent of that order of lag. The order, p , is the maximum order of lags found to be related to the current value, after which the larger orders seem to be unrelated to the current value. The number d simply indicates the order of difference. Since the first-order difference is used for the daily and weekly data, the d for them is 1. Similarly, the second-order difference is used for the monthly data, so the d for it is 2. The number q is for the moving average (MA) in the ARIMA. The MA asserts that the regression error for the current value is dependent on the previous regression errors. The formula for MA (q) is as follows:

$$DJI_t = c_0 + a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \dots - \theta_q a_{t-q} \quad (5)$$

Where c_0 is a constant, θ_q is the coefficient for the past errors. Similar to the AR, the maximum order of previous errors, after which the errors seem to be unrelated to the current regression error, is denoted as q . The exact number for it is determined by the Autocorrelation Function (ACF). Like PACF, if the ACF of a certain order of the error is outside a certain threshold, then it indicates that the current regression error is likely to be related to that order of regression error. Finally, it is the ARIMA, which combines the AR and the MA. It can be expressed as:

$$DJI_t = \phi_0 + \sum_{i=1}^p \phi_i DJI_{t-i} + a_t - \sum_{i=1}^q \theta_i a_{t-i} \quad (6)$$

This paper uses this model to predict the stock price that would have been without the interest rate increase based on past information.

3. Empirical Results and Analysis

3.1. Determining the Order for ARIMA

This section will describe the process of determining the order for the ARIMA (p, d, q) model, more precisely, finding the suitable values for p and q . Begin with the daily data. For the order of the AR, the PACF value for the first 40 lags is computed. At a 95% percent significant level, the confidence band (the grey part in the figure) is the threshold mentioned in the previous section. If the dot lies outside the grey area, then it indicates the current value is likely to be related to that order of lag.

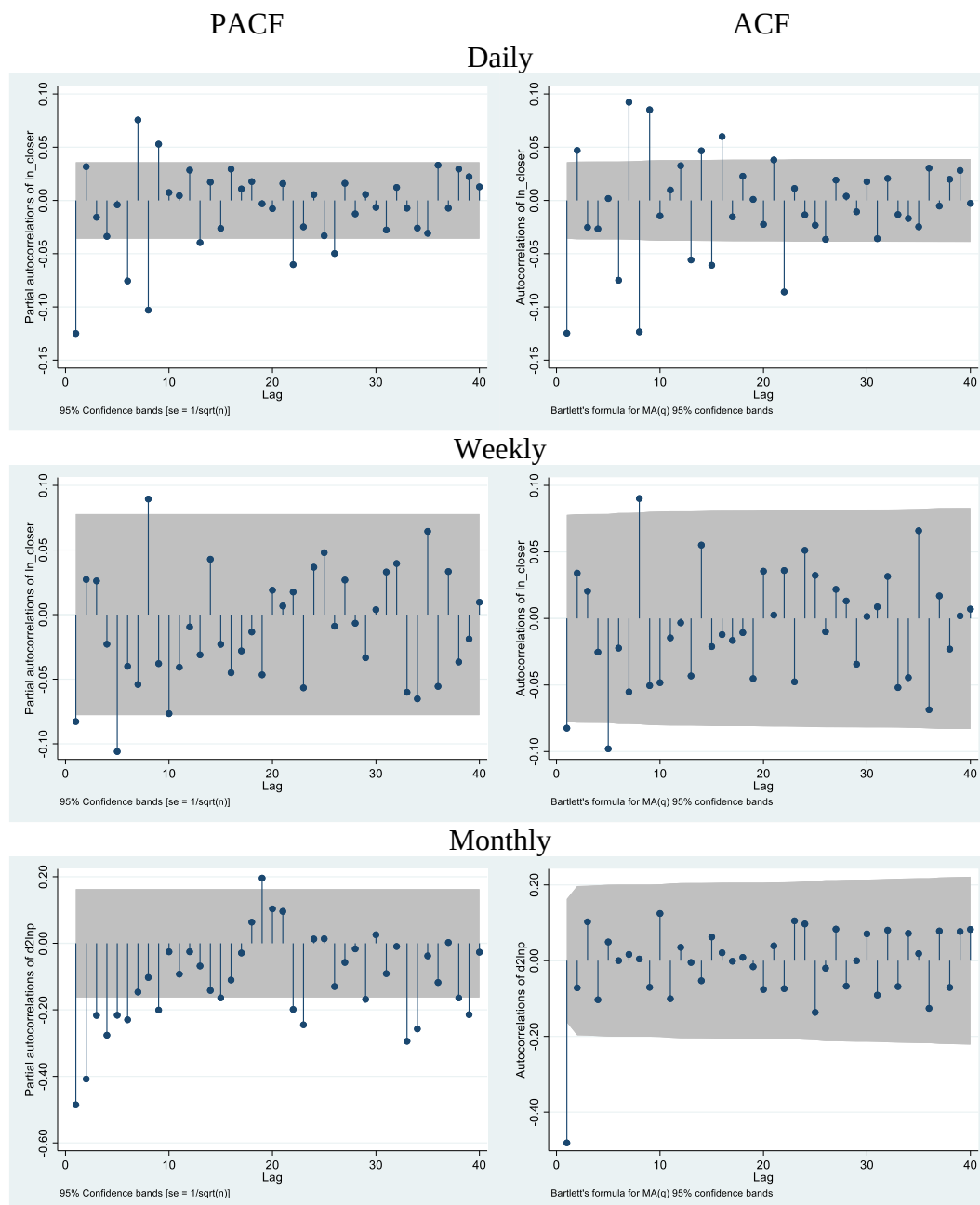


Figure 1. ARMA (p, q) identification (Photo credit: Original)

In Figure 1, Daily PACF, the dot for the 10th order lies outside the confidence band, and most of the dots after it are within the confidence band. This suggests that it is appropriate to set the AR order for the daily ln.close.r to be 10, meaning that the current value is related to first 10 lags. The order is set to be 10 instead of larger numbers despite the fact that there are a few significant lags after the 10th one for simplicity of calculation. For the order of the MA, similar mechanics are used, except

the ACF is used instead of the PACF. In Figure 1, Daily ACF, the 10th dot is outside the confidence band. Again, for simplicity, the larger orders of lags are discarded even though there are some of them having dots lying outside of the grey area. Thus, the ARIMA (p, d, q) for the daily ln.close.r is ARIMA (10, 1, 10). Next, the process for the weekly ln.close.r is almost identical. Using the same method of decision, Figure 1, Weekly, suggests that the ARIMA model for weekly ln.close.r is ARIMA (8, 1, 8). Finally, it is the monthly data. As mentioned in the previous section, because there exist no significant orders of lags for the first-order difference of ln.close.r, the second-order difference, d2.ln.p, is employed. The test for the PACF and ACF are all done with the second-order difference values. It can be inferred from Figure 1, Monthly, that the ARIMA model for the monthly d2.ln.p should be ARIMA (9, 2, 1). Now, the models used to predict the stock price are tested: whether the residual prediction errors are white noises. The null hypothesis of the residual test is that the prediction errors are white noises. Table 2 shows the results of the tests on the daily, weekly, and monthly residual errors. The p-values for all the tests are larger than 0.1000, suggesting that the null hypothesis cannot be rejected on a 10% confidence level. This indicates that the ARIMA model is suitable for predicting the stock price.

Table 2. Residual test

Model	Portmanteau (Q) statistic	Prob > chi2
Daily-ARIMA (10, 1, 10)	47.9109	0.1826
Weekly-ARIMA (8, 1, 8)	16.9072	0.9995
Monthly-ARIMA (9, 2, 1)	37.4440	0.5859

3.2. Results and Explanations

With the suitable model, the predictions for the stock price that would have occurred without the interest rate increase can be made. The models are focused on the first-order (daily and weekly) and second-order (monthly) differences, and the differences are based on the logarithm of the prices. Thus, it is necessary to convert the predictions of the daily and weekly ln.close.r and the monthly d2.ln.p back to the price of the stocks. The method of reversing the calculation is straightforward, so it is not discussed here. Figures 2, 3, and 4 show the results of the predictions for the price in different time spans.

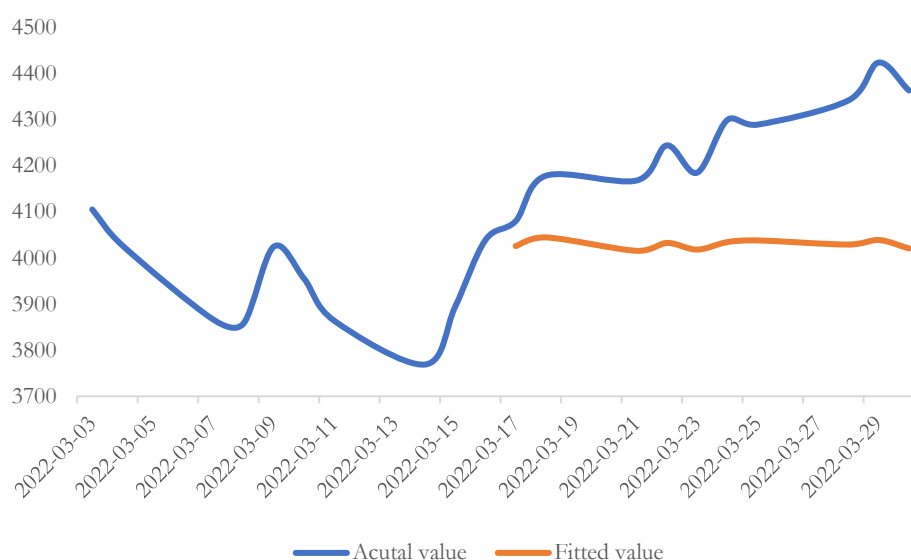


Figure 2. Actual value and fitted value, daily (Photo credit: Original)

In Figure 2, it can be seen that the actual stock price rose above the fitted price in the time span of a couple of days. According to macroeconomic theory, with a higher level of interest, investors who have extra money on hand would be more willing to buy government bills and bonds, thus lowering the demand for corporate stocks and making the prices of stocks go down [9]. However, that wasn't

the case for the next few days after the Fed initially announced its interest rate increase. A possible explanation for this might be that the market has not reacted efficiently to this new piece of information. The newly imposed macroeconomic policy needs time to take effect on the whole economy [10]. The majority of investors remained willing to purchase technology industry stocks.

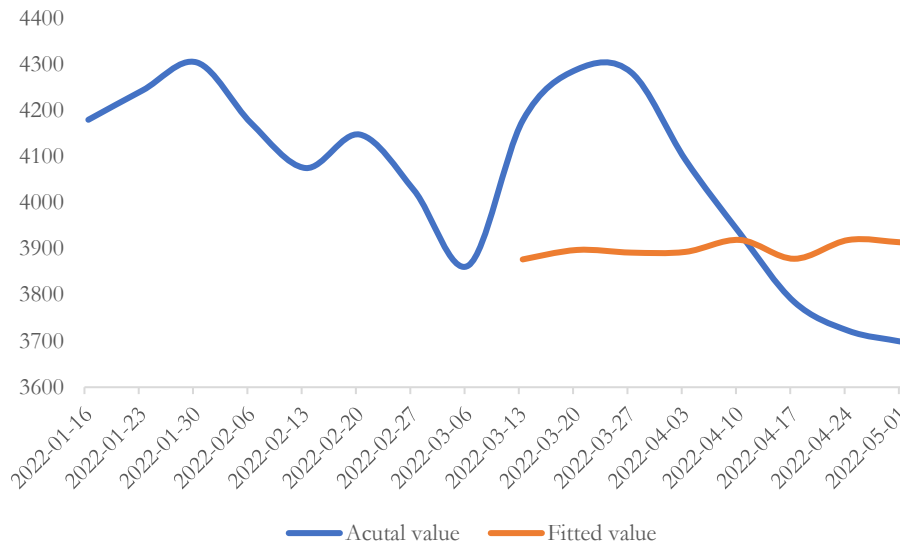


Figure 3. Actual value and fitted value, weekly (Photo credit: Original)

In Figure 3, which represents the weekly prices, there exists a significant downward-sloping trend in the line for the actual price when compared to the fitted value. Even though the average difference between the actual price and the predicted price is not largely below zero compared to the stock price itself, it is obvious that in the earlier weeks, the actual price was higher than predicted, and later the actual price became lower than predicted. The market seemed to adjust according to the monetary policy after a certain period of time. Figure 4 shows the actual and predicted price in a much longer time span. The actual price had always been under the predicted price. The Fed implemented a total of eight interest rate increases in the following months after March 17, 2022. The actual stock price, which was around \$3200 and \$3600 from June to December 2022, was approximately a quarter lower than the predicted price of around \$4200. The stock price dropped severely during these months, indicating that the interest rate spike had a large effect on the technology market.

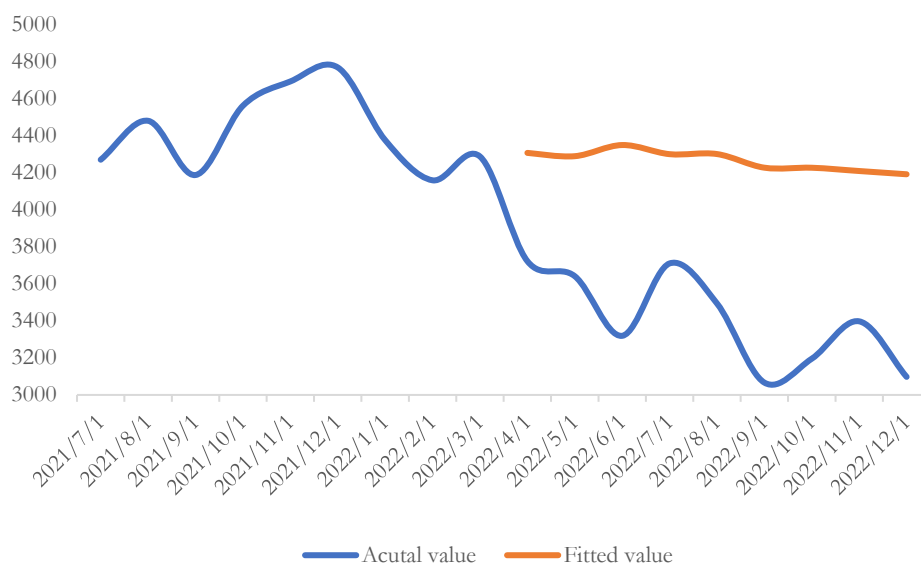


Figure 4. Actual value and fitted value, monthly (Photo credit: Original)

4. Discussion

The results of the analysis above have some similarities and differences when compared to similar past research. First, the empirical results are consistent with the conclusion that a higher interest rate should be related to a lower stock price. However, in this paper, it is suggested that the decrease in the stock price is the result of the rise in interest rate, implying a causal relationship. This contradicts the conclusion from the study concerning the HIBOR and general stock price in Hong Kong, which is that there is no significant causal relationship. Moreover, it is suggested in that paper that the market would react efficiently, whereas, in this paper, it is found that there were a couple of days when the market did not drive the stock price down accordingly after the interest rate increase. It can be learned from this study that raising interest rates to cool down an overheating economy is sure to have a negative impact on the technology industry, even though the effect might come with a small delay. For policymakers, it is suggested that efforts to counter the impact of an overheating economy, such as inflation, ought to be done on an appropriate scale. The interest rate spikes led to a decrease in the Dow Jones Technology stock price on the scale of around a quarter when compared to the predictions without the monetary policies. The substantial negative effect should be taken into consideration. For investors, it is suggested that one should prepare himself for a significant drop in the technology-related stock price in the following months after contractionary monetary policies like this one. However, one need not scramble to liquefy the stocks because the market is probably not going to react instantly.

5. Conclusion

This paper found that interest rate increases, which is a contractionary monetary policy used by the Federal Reserve to fight inflation, are capable of having a significant impact on the technology industry in the long run. The ARIMA model is employed to generate predictions of the stock price that would have occurred without the interest rate increase and *ceteris paribus*. It is concluded that the market did not respond efficiently by driving down the stock price of the technology industry in the time span of a few days. The stock price actually rose higher than the predicted price. In the time span of a few weeks, though, the trend of a decreasing stock price is clear, with the initial weeks having higher-than-predicted stock prices and the later weeks having lower-than-predicted ones. In longer time horizons of a few months, the negative impact on the price is significant. The stock price was approximately a quarter less than the predicted stock price without the interest rate increase. The results from the monthly analysis fit the explanation that higher interest rates should discourage investing in stocks, because it would be more beneficial to buy government bills and bonds, and the value of the US dollar would increase, leading to less export from the technology industry.

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