Research on the Relationship between Apple Stock Price and Changes in Exchange Rate: Evidence from Fed's Rate Hike

Gengyuan Zhang

Department of Economics, Queen's University, Kingston, Canada

19gz3@queensu.ca

Abstract. The Fed's Rate Hike changes the exchange rate, which would fluctuate the stock price. This paper uses VAR model and ARMA-GARCH model to determine the relationship between the exchange rate change and Apple stock price from January 2022 to July 2022. The impulse-response estimation suggests that the exchange rate seems to be a slight short-term external shock, and the ARMA-GARCH regression implies that the exchange rate affects the stock price significantly, which is lagging as well.

Keywords: Apple stock price; Exchange rate changes; The Fed's rate hike.

1. Introduction

The Fed's rate hike refers to a federal funds rate rise after the Board of Governors of the Federal Reserve System decides on the adjustment of monetary policy after its meeting in Washington. A rate hike is a tight monetary policy, that Fed increases interest rates as a response to the current economic situation. A rate hike usually increases interest rates, which reduces the money supply. In addition, the increase in the dollar exchange rate will affect the economy as well. For example, after the appreciation, gold price would fall, and US dollars would be preferred to hold so that other countries' currencies would depreciate.

Fed announced to increase the interest rate for the first time on March 16, 2022. Rates would rise by 25% point, which would increase the interest rate into the range by 0.25% - 0.5%. This is the first rate increase after the last one in 2018, which is almost 3 years ago. The Fed officials suggested that the rate rise would occur along with economic growth at a slow rate since this would directly present financing costs higher for consumers borrowing and credit [1]. The FOMC indicated several domestic economic conditions as the main causes, as well as the risk of Russia's war on Ukraine that would produce much higher inflation and a drop-in economic activity. In addition, it was expected to reduce the Fed's balance sheet someday [2].

After the following rate increase by 50 basis points, or 0.5%, on May 4, 2022, the Fed raised the interest rates by 75 basis points, which is the most radical one since 1994, which would take the level of its rate to the range of 1.5% to1.75%, the highest since the pandemic. In addition, the Fed cut 2022 economic growth outlook as well, to 1.7% of GDP, 2.8% lower than March 2022. In the committee's statement, an optimistic economy picture with higher inflation was drawn, which was approved by almost all FOMC members [3]. Most recently, Fed continued to raise the rate by 75 basis points on July 27, 2022, which would reach 2.25% to 2.5%, the highest level since 2018. Under the worry that the Fed would eventually lead to a recession, it was explained that "the central bank would slow its hike if a recession occurred while inflation was still high" [4].

Plenty of papers focused on this topic, one of which is the work by Ji. It is believed that almost all global markets would be affected, such as bond markets, and stock markets. For US domestic market, different sectors of the stock market would also perform diversely and "suffer a certain effect", as well as the growth sector. In the meantime, they argued to "guard against the negative impact of the Fed's interest rate hike spillover effect on the economy". Even though they provided the suggestion most for China, this is inductive for all economic entities in the world [5].

The impact of the Fed's rate hike on the exchange rate has been analyzed by many works. Utku Özmen and Yilmaz used the wavelet coherency analysis to check the relationship between exchange rate change and its determinants, including the monetary policy of Fed, and recorded "the changing

nature of the correlation". They showed that there is a co-move relationship between the emerging market exchange rate and Fed's monetary policy. In addition, the co-movement is "not uniform across frequencies", which is not consecutive during the period or even entirely disappears, thus it could be discussed across various periods and frequencies [6]. As a specific case study, Lei specified its impact on Russian economy. The Fed's rate hike increases the volatility of Russian economy, which reflects on Russian currency value. Lei provided empirical evidence that after the American increase in interest rates, the ruble devaluated quite a lot, leading to several harms to Russian economy as well as increasing the movement of Russian economic transformation and monetary policy flexibility [7].

The relationship between exchange rate and stock price was discussed widely as well. Wong used "the constant conditional correlation (CCC) or dynamic conditional correlation (DCC)–multivariate generalized autoregressive conditional heteroskedasticity (MGARCH) model" to estimate the relationship between real exchange rate returns and real stock price returns in Malaysia and 6 other countries. The model results imply that the relationships in Malaysia, Singapore, Korea, and the UK are significantly negative while those are insignificant in the other countries. Hence Wong concluded that the exchange rate market is essential to the stock market [8]. More precisely, Ma and Kao examined two possible effects on stock price by the value of a country's currency. They suggested that there are two sorts of foreign exchange risks, the transaction exposure and the economic exposure from firms' discounted cash flows. With corresponding hypotheses and estimation results, they offered two possible influences. The fluctuation is the risk faced by investors as exchange rate levels are correlated with preferred stock price movement. Moreover, the effect differs in the export-dominant country and export-dominant countries, which would reduce the competitiveness in the former market but decrease the costs in the latter one [9]. According to both articles, it is certain that there exists an apparent impact on stock markets.

It has been shown that the Fed's rate hike would concuss international exchange rates, and exchange rate waves are strongly related to the stock prices. The previous works form the premise and foundation of this work.

This paper applies the methodology of the work by Duan. Duan built an ARMAX model, a VAR model, and an ARMA-GARCH model in order to check the change in American Airlines stock price and its volatility, given the background that stock prices suffered from the outbreak and shut-down of COVID pandemic. As an external shock for the stock market, the exchange rate fluctuation is likely to affect the stock prices, therefore it is suitable to apply the method of Duan's paper. In this paper, VAR and ARMA-GARCH models would be estimated, which would be specified in the following parts [10].

The following parts of this paper are organized as follows: Part 2 is the research design, which contains the data source, unit root test, and model specification; Part 3 is the results and analysis of estimations, including VAR model identification, impulse, and response, ARMA model identification and ARMA-GARCH estimation result; Part 4 is discussion, where several topics would be specified, such as different from current literature, and advice for policy-makers and investors; Part 5 would offer the main conclusion of this paper.

2. Research Design

2.1 Data source

Data on the exchange rate (US dollar to RMB) is from China Foreign Exchange Trade System and National Interbank Funding Center, which is the official institution for public RMB exchange rate data. Given the background of the Fed's Rate Hike in 2022, data from January 4, 2022, to July 15, 2022, are collected, apart from weekends and holidays. The stock prices of Apple are collected from CSMAR, which are collected daily from January 4, 2022, to July 8, 2022, in which the closing prices of Apple stock price are the main analyzing targets.

As stock prices would merely be recorded during the trade days, this paper matches them with the exchange rate data. Exchange rates of non-trade days have been omitted and remaining data are

rearranged, which would not affect the result of this research. With the treated data, log-stock price and exchange rate, as well as log returns of stock price and exchange rate, are calculated. Stata would be the main tool used to do tests and estimate regressions.

2.2 Unit Root Test

For the purpose of checking the stationary of given time series, a unit root test would be applied. The stationary of a time series is a key promise in analyzing and modeling such a series. If the time series is not stationary, it would be difficult to reflect past and future through models. Therefore, it is necessary to check the stationary of the series.

Table 1. ADF test

	Variables	t-statistic	p-value
Price			
	Apple	-2.389	0.3854
	US-RMB	-1.874	0.6680
Yield			
	Apple	-7.826	0.0000***
	US-RMB	-7.915	0.0000***

According to the table, it would be found that the log-price of both Apple stock price and US dollar-RMB exchange rate is not statistically significant at 95% confidence level, i.e., not stationary under 95% confidence interval. Nonetheless, if the logarithm of rate of return by both variables is taken, it turns out to be quite significant. In other words, log returns of Apple stock return and the exchange rate are both statistically stationary. Thus, based on the conclusion above, the logarithm of returns would be considered to build models.

2.3 VAR Model Specification

When multiple economic variables are about to be estimated, instead of estimating each variable in a single-variable time series method, such as MA models, it is preferred to treat them as a system and make estimations together, in order to guarantee the mutual consistency of the estimation, which is called "multivariate time series", including the Vector Autoregression (VAR) model put forward by Sims [11].

Suppose two time series variables ($y_{1t}, \quad y_{2t}$), as dependent variables of two regression models, accompanied with p-lag term of these two variables, therefore the bivariate VAR(p) system would be:

$$\begin{cases} y_{1t} = \beta_{10} + \beta_{11} y_{t,t-1} + \cdots + \beta_{1p} y_{1,t-p} + \gamma_{11} y_{2,t-1} + \cdots + \gamma_{1p} y_{2,t-p} + \varepsilon_{1t} \\ y_{2t} = \beta_{20} + \beta_{21} y_{1,t-1} + \cdots + \beta_{2p} y_{1,t-p} + \gamma_{21} y_{2,t-1} + .. + \gamma_{2p} y_{2,t-p} + \varepsilon_{2t} \end{cases} \quad (1)$$

Where $\{\varepsilon_{1t}\}$ and $\{\varepsilon_{2t}\}$ are white noise, which is not autocorrelated, nevertheless, there may exist contemporaneous correlation:

$$Cov(\varepsilon_{1t}, \varepsilon_{2t}) = \begin{cases} \sigma_{12}, & t = s \\ 0, otherwise \end{cases} \quad (2)$$

Put two sectors in equation (1) together and suppose $y_t = \begin{pmatrix} y_{1t} \\ y_{2t} \end{pmatrix}, \varepsilon_t = \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix}$, then

$$y_t = \begin{pmatrix} \beta_{10} \\ \beta_{20} \end{pmatrix} + \begin{pmatrix} \beta_{11} & \gamma_{11} \\ \beta_{21} & \gamma_{21} \end{pmatrix} y_{t-1} + \cdots + \begin{pmatrix} \beta_{1p} & \gamma_{1p} \\ \beta_{2p} & \gamma_{2p} \end{pmatrix} y_{t-p} + \varepsilon_t \quad (3)$$

Which is the VAR(p) model, in which {εt} is the vector white noise process.

In the VAR estimation, an impulse response function is a method to reflect how much the other variables would change during the period, given one unit of external shock, specifically, it would be expressed as:

$$\frac{\partial y_{t+s}}{\partial \varepsilon_t'} = \Psi_s \tag{4}$$

Which infers the impact on $y_{i,t+s}$ in the (t+s)-th period when the disturbance term $\varepsilon_{j,t}$ of the j-th variable rises by 1 unit in the t-th period, while other variables and disturbance variables hold. If treat $\frac{\partial y_{i,t+s}}{\partial \varepsilon_{jt}}$ as the function of time interval, s, the equation would be the impulse response function (IRF). IRF could be visualized, which is an essential method to analyzing VAR model.

2.4 ARMA-GARCH Model Specification

ARMA-GARCH model consists of ARMA model and GARCH model, which would be introduced step by step.

Cross section data is likely to exist in heteroskedasticity and time series data is usually autocorrelated, while time series would also exist "Autoregressive Conditional Heteroskedasticity" (ARCH), pointed out by Engle [12]. Before the publishment of Engle's paper, due to the lack of more fitted measurement, economists had assumed that the variance of time series is constant [12]. Nevertheless, it seems that observations with large variance appear to take place together, and those with smaller variance occur together, or by the name of "volatility clustering". When the current period or past period fluctuates a lot, the variance of the next few periods would be relatively significant as well. Since the fluctuation of variance is in consideration in ARCH model, it would be much more fitted in variance forecast. Generally, the "ARCH (1) disturbance term" would be:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \cdots + \alpha_p \varepsilon_{t-p}^2 \tag{5}$$

Where the σ_t^2 is the conditional variance of the disturbance term ε_t, and α_0 is constant.

In ARCH(p) model, if p is large, the sample size would be lost as plenty of parameters need to be estimated, therefore Bollerslev put forward GARCH model, which includes the autoregressive part of σ_t^2, based on ARCH model [13]. Precisely, GARCH (p, q) is designed by:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \cdots + \alpha_q \varepsilon_{t-q}^2 + \gamma_1 \sigma_{t-1}^2 + \cdots + \gamma_p \sigma_{t-p}^2 \tag{6}$$

Where α_0, α_1, γ_1 would all be positive in order to guarantee positive σ_t^2. Moreover, GARCH (1,1) is equivalent to ARCH model with infinite terms. If considering σ_{t-1}^2 as a variable, then high-level ARCH(p) model could be expressed as GARCH (1,1).

3. Results and Analysis

3.1 VAR Model Identification

First of all, in order to build a VAR model, the order p of VAR(p) ought to be determined. Based on the VARSOC command from Stata, which shows as Table 2, it indicates that a VAR (21) model would be suitable to estimate, according to the LR test result.

Table 2. VAR identification

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	594.264				8.8e-09*	-12.8753*	-12.8532*	-12.8205*
1	596.013	3.498	4	0.478	0.000	-12.826	-12.760	-12.6619
2	600.135	8.245	4	0.083	0.000	-12.829	-12.718	-12.5549
3	602.849	5.427	4	0.246	0.000	-12.801	-12.646	-12.4173
4	606.600	7.502	4	0.112	0.000	-12.796	-12.597	-12.3023
5	609.691	6.182	4	0.186	0.000	-12.776	-12.533	-12.1729
6	612.865	6.346	4	0.175	0.000	-12.758	-12.470	-12.0452
7	613.671	1.614	4	0.806	0.000	-12.688	-12.357	-11.8662
8	615.123	2.903	4	0.574	0.000	-12.633	-12.257	-11.7011
9	618.161	6.077	4	0.193	0.000	-12.612	-12.192	-11.5706
10	620.681	5.040	4	0.283	0.000	-12.580	-12.115	-11.4288
11	622.768	4.173	4	0.383	0.000	-12.538	-12.030	-11.2775
12	627.071	8.607	4	0.072	0.000	-12.545	-11.992	-11.1745
13	627.382	0.622	4	0.961	0.000	-12.465	-11.867	-10.9846
14	628.447	2.130	4	0.712	0.000	-12.401	-11.759	-10.8112
15	632.583	8.272	4	0.082	0.000	-12.404	-11.718	-10.7045
16	633.280	1.393	4	0.845	0.000	-12.332	-11.602	-10.5231
17	634.726	2.892	4	0.576	0.000	-12.277	-11.502	-10.3579
18	638.709	7.966	4	0.093	0.000	-12.276	-11.458	-10.2479
19	642.759	8.100	4	0.088	0.000	-12.277	-11.414	-10.1393
20	651.362	17.206	4	0.002	0.000	-12.377	-11.470	-10.1298
21	660.306	17.887*	4	0.001	0.000	-12.485	-11.534	-10.1276
22	662.296	3.981	4	0.409	0.000	-12.441	-11.445	-9.97425
23	667.036	9.480	4	0.050	0.000	-12.457	-11.417	-9.88069
24	671.110	8.149	4	0.086	0.000	-12.459	-11.375	-9.77267

The stability condition of VAR estimates needs to be checked, which could be drawn a graph of the unit circle to visualize the result. From Figure 1, it appears that all eigenvalues are in the unit circle, thus the VAR model meets the stability condition.

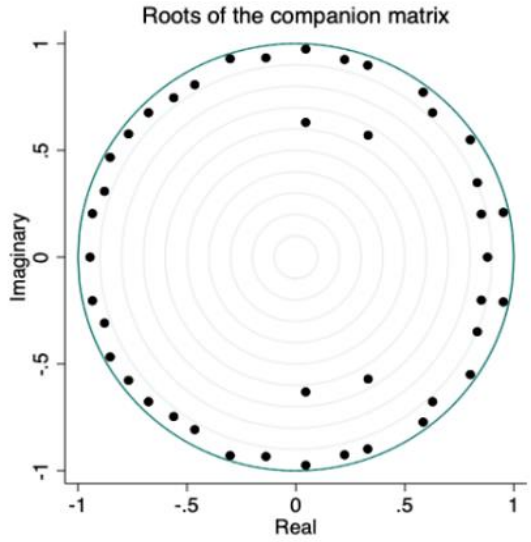

Figure 1. VAR stability

3.2 Impulse and Response

Figure 2 indicates the result of impulse response estimation. It implies that when the exchange rate fluctuates, future Apple stock price, or the rate of return, would concuss slightly. Specifically, in the period of t=0, if the rate of return of the exchange rate rises by 1%, the future yield of Apple stock

would concuss slightly with the amplitude of 0.1%. As for the time effect, it would gradually decrease with time and eventually converge to 0. It appears that the influence on Apple stock from exchange rate change seems like a short-term small external shock.

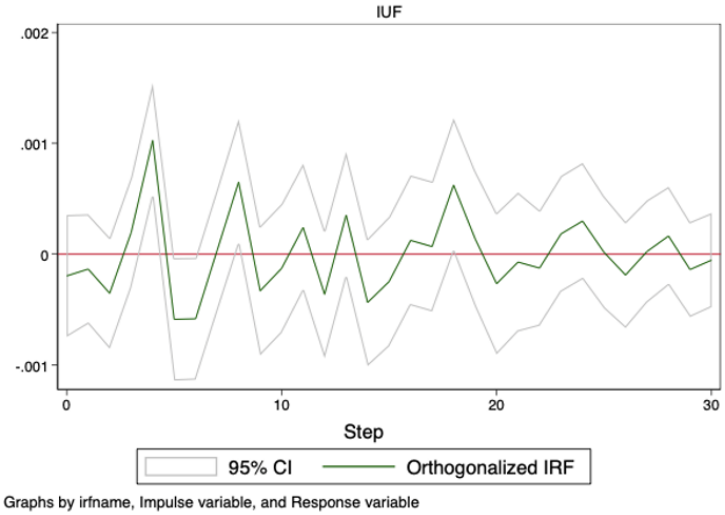

Figure 2. Impulse and response

3.3 ARMA Model Identification

In order to build an ARMA model, it is necessary to find out AR and MA models. With the help of partial autocorrelation plot (PACF) in Stata, whose result shows in Figure 3, it seems that the lag 12 terms would affect the data significantly, or AR (12) would be proper in this circumstance.

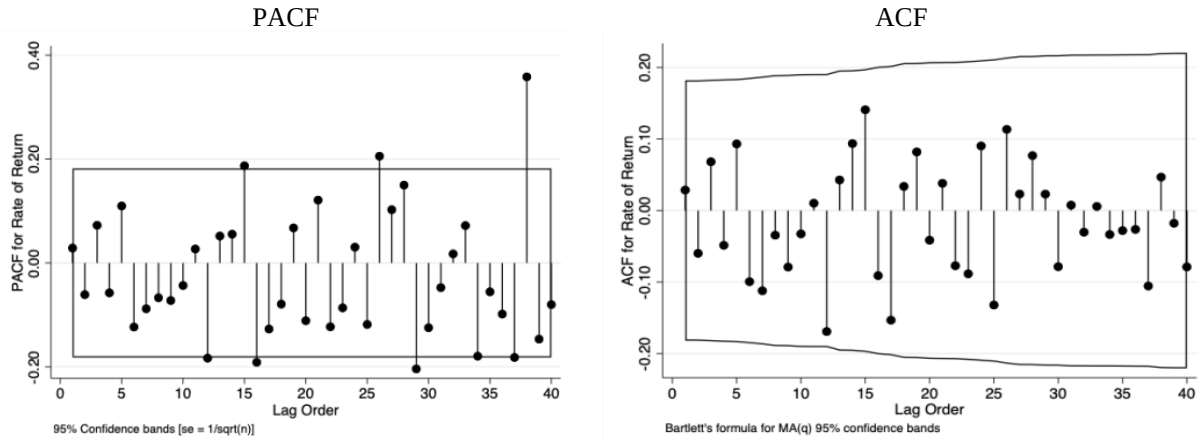

Figure 3. PACF and ACF, Apple

Autocorrelation Plot (ACF Plot) from Stata is applied here to figure out the suitable order of the MA part of the model, which shows in Figure 3. It indicates that there does no existing order of MA, hence there is no need to estimate the MA section in this model.

3.4 ARMA-GARCH Estimation Result

GARCH model should be conducted on the condition of conditional heteroscedasticity in the raw data. Based on the estimation result of variance equation, as Table 3 shows below, the GARCH terms from column 1 to column 3 are all quite significant, which implies that there exists conditional heteroscedasticity of Apple stock price, thus the premise of GARCH model is satisfied. From the estimated coefficient of exchange rate, the fluctuation of exchange rate in period T=0 has a significant impact on volatility; however, this effect is absorbed when the lagged on-stage exchange rate is added. After adding the exchange rate returns of the current period lagged period 1 and lagged period 2, it

could be found that the coefficient of lagged period 2 exchange rate returns is 246.6379, which is significant at 95% confidence level, implying that exchange rate has a significant impact on the daily volatility of Apple stock, which is lagged.

Table 3. ARMA-GARCH estimation results, variance equation

	(1)	(2)	(3)
Exchange rate			
T=0	252.9268***	236.7934	88.30899
	(81.3669)	(154.5858)	(886.54879)
T=-1		55.5755	-80.1690
		(241.3082)	(59.2710)
T=-2			246.6379**
			(108.3562)
GARCH (1, 1)			
ARCH (-1)	-0.0463	-0.0364	-0.2253**
	(0.0582)	(.0790)	(0.1082)
GARCH (-1)	0.8701***	0.8248***	1.0879***
	(0.1358)	(0.1374)	(0.0380)
Constant	-9.9398***	-9.7379***	-10.5586***
	(0.5979)	(0.5687)	(0.7673)

4. Discussion

This paper finds out that the exchange rate change does have an impact on Apple's stock price. Nevertheless, the effect is neither wide nor far-reaching. At the beginning of exchange rate fluctuation, the yield of stock price would concuss slightly as well, and gradually the impact would decline and disappear. Moreover, even though the influence is quite prominent, it would be absorbed in the future, which infers that the effect should be lagging.

This result is fitted to the conclusion of Wong. The exchange rate does harm the stock price, and the effect is significant at 5% level, even though Wong discussed the impact from macroeconomic view. However, a little different from Ma and Kao's work is that it seems not to change the confidence of investors a lot. The undulation was relatively little in scale. This may be explained by, for an international major company, it is hard for investors to lower their expectations of such a company.

This result is meaningful to the policymakers. When considering applying tight fiscal policy, it would be worried that the stock prices of firms would be damaged, as often as not. This paper indicates that firms, at least major companies, such as Apple, can deal with this shock. Rather they ought to forecast the situations in the future, owing to the lagging effect.

This is also inductive to the investors. The exchange rate undulation is likely to be a small-scale external shock, therefore there is no need to worry too much about the stock situation of Apple, even if it would wave little in the short term. However, they need to bear in mind that the wave has an impact on future stock as well, which is reflected in the lagging term in the model here.

5. Conclusion

This article examines how the exchange rate would affect Apple stock price. The Fed's rate hike concussed the exchange rate greatly. In the VAR model, the impulse and response estimation shows that the impact did not affect Apple's stock dramatically. In addition, it is short-term, which would decline and finally become zero. From the view of ARMA-GARCH model, the coefficient in lagged period 2 shows significance at 5% level. Thus, the influence is remarkable but lagged. Nonetheless, there remain further questions for discussion, such as the reason why the effect is lagged rather than current. It could also be argued if there exist more fitted estimations. These questions could be specified in further research.

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