The Impact of the Federal Rate Hike on TSMC: Based on Time Series

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Abstract. On July 27th 2022, the US Federal Reserve raised interest rates for the fourth time this year. The benchmark interest rate grew to a range of 2.25%-2.5%, making it the most stringent consecutive action since 1990s. Until now, the Fed has raised interest rates 225 basis points this year. During this period, the increase of Federal rate has a great impact on many companies, especially companies depending on the international trade. Taiwan Semiconductor Manufacturing Company (TSMC) is a typical company that relies on the international trade. So, to identify the impact of the Federal rate hike, this paper takes TSMC as example and intercepts its stock data from June 2021. By using Var model and AMAR-GARCH model to analyse the data, this paper study how the TSMC stock has been affected. This paper found that TSMC stock will be affected by the rate hike, but the effect is beneficial, probably because of the company's advancing place in technology.

Keywords: Federal Rate Hike, TSMC, Time Series.

1. Introduction

In March, the Federal Reserve System increased its target for the its funds' rate by 25 basis points from near zero, kicking off an inflation-busting tightening cycle. In early May, the Fed announced another half-point rate hike. Then the US Fed issued an interest rate increase of 75 basis points on June 15 to curb inflation. It was the Fed's biggest rate increase since 1994. At a news conference, Fed Chairman Jerome Powell said the latest 75 basis point rate hike was "unusually" large, but that the next 50 to 75 basis point increase was still expected to be possible to bring inflation back to normal. On July 27, the Federal Reserve boosted interest rates again. The rate increase was 75 basis points, in line with the Fed's earlier signals and market expectations. So far, the Federal Reserve has increased the federal funds rate 225 basis points this year.

The Fed's balance sheet ballooned from $4.2tn in February 2020 to nearly $9tn by the end of 2021 through successive injections of liquidity into markets. But after extremely loose monetary policy, the market also welcomed the aggressive tightening of the Fed's strict policy, as expected. According to data from the US Labor Department on August 10, the US consumer price index (CPI) grew 8.5 percent in July from a year earlier, below market expectations of 8.7 percent, easing pressure on the Federal Reserve to continue to hike interest rates aggressively.

But at the same time, the economic impact of its previous rate increases is starting to show. Tight monetary policy actually dampens global demand and slows growth in emerging markets, which will lead to the decrease of profit in many companies.

Based in Hsinchu, Taiwan, Taiwan Semiconductor Manufacturing Corporation, is the world's largest and best chipmaker, more than half of the world's chips come from TSMC. TSMC is the leading contract chipmaker thanks to its partnership with Apple. It could take a decade for its main rival, Samsung Electronics, to catch up with TSMC, which has become the center of the chip supply chain.

In 2011, with a capitalization of about NT$259.15 billion, it is the largest company in Taiwan stock market by market capitalization. With the unique business model, TSMC has led the gathering, improvement, and growth of Taiwan's semiconductor industry, which has made Taiwan a global semiconductor and IT industry hub, and made the technology and electronics industry a backbone of the economic structure. However, countries with economic and technological strength set their eyes on the foundry industry. Through industrial support, Samsung in Korea, Global foundry in Singapore

and SMIC in mainland China have shown their great power in this market. Today, TSMC retains a global market share of about 50 percent.

To ascertain the effect of the federal funds rate increase on the TSMC fund, the paper takes TSMC stock to find out the answer.

2. Literature Review

2.1. Research about Federal Rate Hike

Many scholars have extensively studied the effects of interest rate hike. Kazi, Wagan and Akbar used the TVP-FAVAR method to study the spillover effect of the US monetary policy shock from the first quarter of 1981 to the fourth quarter of 2010 on 14 OECD countries [1]. The findings demonstrate that the Federal Reserve's interest rate hike has a beneficial spillover effect on other member countries while having a negative influence on the economic growth of Canada, Japan, and Sweden. According to Li Tianguo's research, the Federal Reserve's interest rate increase will cause the RMB exchange rate to decline in the short term. The stock price will also rise briefly before dropping, and it won't quickly return to its previous level [2]. Tan Xiaofen explored the spillover effects of the US ending unconventional monetary policies on the economies of 11 emerging economies, and the empirical results showed that the end of the US unconventional monetary policies led to currency depreciation and the reduction of 10-year Treasury yields in emerging economies [3]. Yanlin Sun and Qianting Zhang believed that the Fed's interest rate increase had a time-varying structural impact on China's economic output through two channels: interest rate and exchange rate [4]. Xiao Weiguo and Lan Xiaomei studied the impact of the normalization of US monetary policy on China's economy from November 2008 to March 2017 by using time-varying parameter vector autoregressive model [5]. The empirical findings demonstrate that the Federal Reserve's interest rate hike strategy significantly affects changes in stock and housing prices, prices, and gross domestic product in China through three channels: the interest rate, the exchange rate, and the capital flow.

2.2. Research about Exchange Rate

The mechanism by which the real exchange rate is able to promote economic expansion is also studied by many scholars. The correlation about real exchange rates and economic expansion has drawn increasing attention in recent years [6]. A substantial body of empirical evidence supports the idea that a competitive and stable real exchange rate benefits economic growth, although the precise mechanism underlying this association is still unknown. There is no agreement on the precise channel through which this effect operates because the literature addressing this question is in its infancy. Through reviewing important literature, it is found that there are four main explanations for the mechanism of real exchange rate depreciation promoting economic growth.

2.2.1 The Tradable Sector-led Growth Channel

The "tradable sector-led growth" channel essentially views economic development as a procedure in which real exchange rate undervaluation moves resources from the non-tradable one to the sellable one, hence encouraging economic expansion. This mechanism is also known as the "second-best adjustment mechanism." [7].

2.2.2 The Total Factor Productivity (TFP) Growth Channel

The theory of economic growth has undergone a transformation from the early neoclassical growth theory to the late endogenous growth theory which has become the mainstream theory of economic growth at present. Neoclassical growth theory emphasizes that economic growth originates from exogenous increase in TFP. The transformation from neoclassical growth theory to endogenous growth theory is accompanied by the deconstruction of TFP. The research on total factor productivity and economic growth can provide reference for this paper.

The domestic production structure serves as the central focus of the analysis for the TFP channel. The trading industry is more profitable when the real exchange rate is lower. Resources becomes tradable, which is often more productive, as production adjusts to rising prices. These productivity gains across the economy ultimately lead to an increase in GDP. However, the explanation of how the size of the sellable resources increase productivity is not clear in the literature [8]. Most explanations point to some "learning by doing" effect related to production in the tradable sector [9].

2.2.3 The Capital Accumulation Channel

According to the capital accumulation channel, an undervalued exchange rate increases the capital stock of economy, which promotes growth. This view includes two avenues for accumulating wealth [10]. The first factor is the rise in the sellable sector's share of GDP, which is brought on by increased production and higher profits [11]. The second source is a rise in total saving and investment, which raises the stock of capital [12].

2.2.4 Surplus Labor Transfer Channel

Studying the connection between economic expansion and the exchange rate from the perspective of labor market conditions is a novel research approach. Real wages have a significant role in how exchange rates affect growth because they have an impact on the rate at which capital is returned, which in turn affects how exchange rate policy operates.

2.3. Review of the Literature

Overall, the research on the causes, processes, and impact of the Federal rate hike has been relatively well researched, but there is still relatively little research on the impact of the rate hike on the international company. As a result, this paper aims to fill in some of the research gaps in the field and utilize empirical evidence to show how the rate hike has affected global firms like TSMC.

3. Methodology

3.1. Data Source

This paper uses the Choice financial terminal, a search engine, to search and obtain data on the TSMC stock, to find out the opening and closing prices and stock returns of the companies Taiwan Semiconductor Manufacturing Company, from June 1st, 2021 to August 15th, 2022, as a data source and data basis for empirical analysis to learn the effect of Federal Rate Hike on TSMC stock. In addition, this paper used CEIC Data to obtain the exchange rate of U.S. dollar.

3.2. ADF Test

After completing the model construction, this paper first performs a unit root test (smoothness test) on the model. After putting the data into Stata and performing the ADF test, this paper can reject the initial premise that the model is stable and practicable because it can be shown from Table 1 that the p-value for the log-returns is 0, which is less than 0.1.

Table 1. ADF test

Variables	t-statistic	p-value
	Price	
TSMC	-3.2430	0.0762*
USD	-2.5250	0.3156
	Yield	
TSMC	-14.1720	0.0000***
USD	-13.344	0.0000***

3.3. VAR Model

3.3.1 Model Description

VAR model is used for analyzing two variables. If two independent autoregressive models are built, it is not possible to comprehend the relationship of the two factors. But the relationship between the two variables may be determined if the form is simultaneous. Two parameters are connected to the VAR model's structure, one is the maximum lag order, and the other one is the number of variables.

Take the VAR model with two variables $y_{1,t}$ and $y_{2,t}$ with a lag of 1 period as an instance:

$$y_{1,t} = \mu_1 + \pi_{11.1} y_{1,t-1} + \pi_{12.1} y_{2,t-1} + u_{1t} \quad (1)$$

$$y_{2,t} = \mu_2 + \pi_{21.1} y_{1,t-1} + \pi_{22.1} y_{2,t-1} + u_{2t} \quad (2)$$

Where $u_{1t}, u_{2t} \sim IID(0, \sigma^2),\ Cov(u_{1t}, u_{2t}) = 0$

Specifically, in this paper, y_1 is the return of TSMC stock, while. y_2 represents the exchange rate.

3.3.2 Stability Test

Assume $\Pi_1 = \begin{bmatrix} \pi_{11.1} & \pi_{12.1} \\ \pi_{21.1} & \pi_{22.1} \end{bmatrix}$, the fact that all of the eigenvalues in Π_1 must lie within the unit circle is a necessary and sufficient condition for the stability of the VAR model.

3.3.3 Selection of Lag Period K of VAR Model

The establishment of VAR model should not only satisfy the stationarity condition, but also determine the lag period K correctly. The error term will have significant autocorrelation if the lag period is inadequate. It can remove the autocorrelation in the error term from the VAR model by appropriately raising the value of K (increasing the number of lag variables). On the other hand, K's value shouldn't be excessive. The degrees of freedom will decrease if K is overly large, which will directly impact how well the model parameter estimator works.

Here, this paper selected the value of k with the LR statistic.

$$LR = -2(\log L_{(k)} - \log L_{(k+1)}) \sim \chi^2(N^2) \quad (3)$$

Where k is the maximum lag period of the lagged variable in the VAR model, and $log\ L_{(k)}$ and $log\ L_{(k+1)}$ are the maximum likelihood estimates of the respective VAR(k) and VAR(k+1) models. When the value of the LR statistic is smaller compared to the critical value, it means the new lag variable is not significant in the VAR model.

3.3.4 Impulse Response Function (IRF)

Because of the consistency of OLS estimators of VAR model parameters, it is difficult to make the economic interpretation of a single parameter estimation. So this paper looks at the IRF of the system to analyse the model.

The response of an endogenous variable to an erroneous shock is described by the impulse response function. It describes, in particular, how a shock of one standard deviation on the random error term affects the present and future values of endogenous variables.

$$\frac{\partial y_{t+s}}{\partial \varepsilon_t'} = \psi_s \quad (4)$$

It shows the effect on the value of the number i variable in period (t+s) when the disturbance variable's perturbation term in period t is increased by 1 unit (while the other variables are unchanged from the perturbation terms in other periods). When think of it as a function of the interval s, that's the impulse response function.

3.4. ARMA-GARCH Model

3.4.1 Model Specification: ARMA

$$x_t = \phi_i + \sum_{i=1}^{p} \phi_i x_{t-i} + \alpha_i - \sum_{i=1}^{q} \phi_i a_{t-i} \quad (5)$$

From the function above, it can be seen that, $\sum_{i=1}^{p} \phi_i x_{t-i}$ represents the AR(p) model, which uses the historical returns of TSMC stocks to forecast the future; while $\alpha_i - \sum_{i=1}^{q} \phi_i a_{t-i}$ which uses past volatility to estimate the future and the last part of the model.

Specifically, in this paper, the AR model uses the historical returns of TSMC stock, while the MA model uses an error term to forecast the future.

3.4.2 Model Specification: GARCH

After that, this paper construct ARMA-GARCH models of the returns and volatilities of the TSMC stocks. The exchange rate's time points are used as an explanatory variable in this study and are added to the model to facilitate computation. This article may evaluate the connection between the increase in the federal funds rate and the performance and volatility of the TSMC stock.

The model GARCH (p, q) is set as follows:

$$\alpha_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \cdots + \alpha_q \varepsilon_{t-q}^2 + \gamma_1 \sigma_{t-1}^2 + \cdots + \gamma_p \sigma_{t-p}^2 + \beta E_t \quad (6)$$

In the function above, the term $\alpha_1 \varepsilon_{t-1}^2 + \cdots + \alpha_q \varepsilon_{t-q}^2$ is ARCH part, σ_t^2 is the conditional variance of the disturbance term ε_t, the subscript t indicates that variance changes over time. σ_t^2 depends on the square of the disturbance term in the previous p periods. And the last part of the model βE_t represents the impact of adding exchange rate as explanatory variable.

4. Empirical Results and Analysis

4.1. VAR Order

First, this paper determines the lag period K. To construct the VAR model, the paper needs to identify the lag period and test the stability.

Table 2 shows the results of the VAR-12 model. According to the table, the lag order of the model is order 6.

Table 2. VAR model identification

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	1504.4400				1.2e-07	-10.2907	-10.2806	-10.2655
1	1528.7200	48.5530	4	0.0000	1.0e-07*	-10.4296*	-10.3993*	-10.3540*
2	1530.1500	2.8721	4	0.5790	1.0e-07	-10.4120	-10.3616	-10.2861
3	1531.0700	1.8353	4	0.7660	1.1e-07	-10.3909	-10.3203	-10.2146
4	1533.3600	4.5716	4	0.3340	1.1e-07	-10.3792	-10.2884	-10.1525
5	1540.2900	13.8750	4	0.0080	1.0e-07	-10.3993	-10.2883	-10.1223
6	1546.3500	12.1060*	4	0.0170	1.0e-07	-10.4133	-10.2822	-10.0860
7	1549.0100	5.3340	4	0.2550	1.0e-07	-10.4042	-10.2529	-10.0265
8	1551.1800	4.3298	4	0.3630	1.1e-07	-10.3916	-10.2202	-9.9635
9	1552.8800	3.4037	4	0.4930	1.1e-07	-10.3759	-10.1842	-9.8974
10	1555.1200	4.4844	4	0.3440	1.1e-07	-10.3639	-10.1520	-9.8350
11	1555.9300	1.6218	4	0.8050	1.1e-07	-10.3420	-10.1100	-9.7628
12	1558.0700	4.2709	4	0.3710	1.1e-07	-10.3292	-10.0771	-9.6996

Looking at the unit circle (Figure 1), it can be known that all the eigenvalues are inside the circle, which means the stability can be promised.

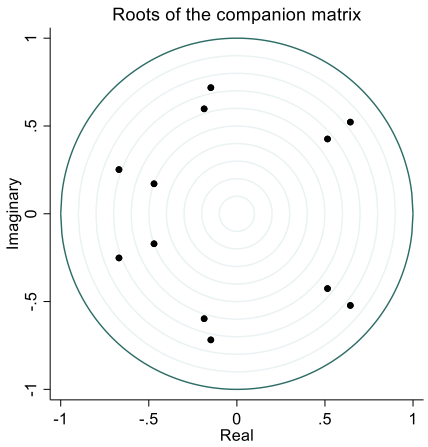

Figure 1. VAR stability (Photo credit: Original)

4.2. Impulse Response Function

From the theoretical analysis, it is certain that the increase of the Federal funds rate will trigger the rise of the demand for dollars in the international floating capital and the international financial market, and further lead to the increase of the exchange rate.

However, the impact of a higher exchange rate on TSMC may lead to the following economic consequences:

First, with reference to the producer theory of microeconomics, this paper assumes that the product prices of enterprises are rigid in a short period. As a large, multinational company listed in the United States, TSMC's main revenue, financial reporting, etc., are calculated in U.S. dollars. To the extent that a stronger dollar means companies earn less money from foreign operations, a Fed rate hike could be a negative for TSMC. Moreover, higher interest rates are bound to boost domestic saving and discourage consumption. This is also one of the negative factors.

Second, the international financial market holds more dollars, which may flow into the stock market or bond market and increase the demand for stocks. In other words, there is a net capital inflow in the American stock market, which may drive up the stock price in the United States.

Based on the above theoretical analysis, it is difficult for this paper to directly judge whether net capital inflow or foreign currency depreciation plays a dominant role in TSMC stock price under the background of Fed interest rate hike.

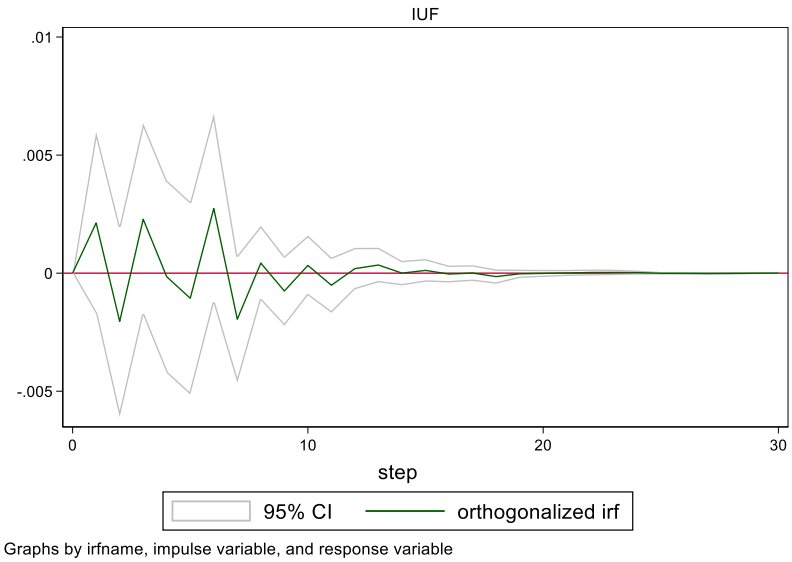

Figure 2. Impulse and response (Photo credit: Original)

According to the estimation results of impulse response (Figure 2), an exchange rate shock of one unit in period t=0 has a negative impact on TSMC return rate in period t=0, and then oscillates around the value of 0, so it is difficult to judge the net impact.

Accordingly, this paper further uses the cumulative response function to calculate the total impact of the current shock on the next 30 periods. As can be seen from Figure 3, the net capital inflow mentioned above dominates the effect.

The reason why the net capital inflow mentioned above dominates the effect is probably because of the monopoly status of TSMC. TSMC leads in technology. It takes an advance advantage of one generation compared with other companies in the same industry. Also, TSMC has the greatest number of patents in the industry. So, to get consumers, competing businesses must imitate TSMC's technologies, which could result in defaults. For example, on November 4, 2009, the US court ruled in favor of TSMC against SMIC for "theft of trade secrets". Subsequently, SMIC transferred 10% of its shares to TSMC, which seriously dented the overall strength of the company.

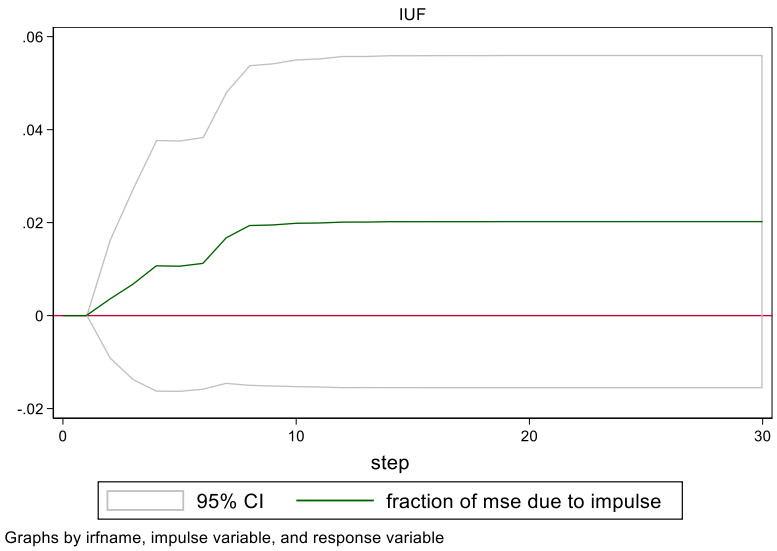

Figure 3. Cumulative response (Photo credit: Original)

4.3. ARMA Order

In this section of the article, it is first necessary to order the first log-return series using the PACF and ACF pairs, the results of which are shown in Figure 4.

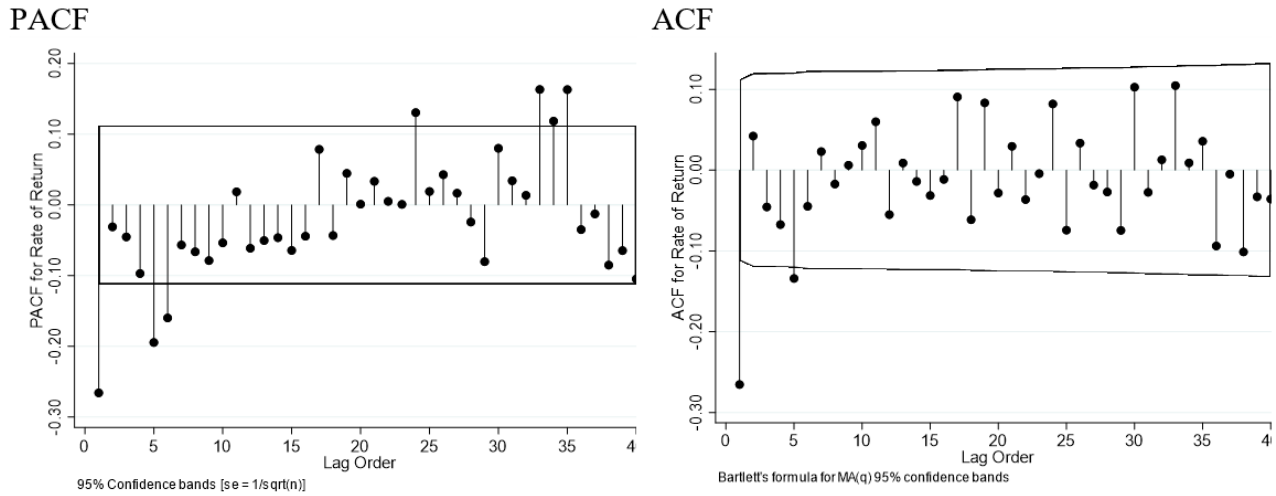

Figure 4. PACF and ACF (Photo credit: Original)

First, this paper needs to order the log returns of the first semiconductor and present the results in the figure above.

From the fixed order result of the two images in the first row in Figure3, the first part beyond the x-axis is 6, so AR(P) is of order 6, MA(q) is also of order 6. i.e., the value of p and q is 6.

Then this paper needs to order the log-returns of the TSMC stock and present the results in the figure above.

From the fixed order result of the two images in the second row in Figure1, the first part beyond the x-axis is 6, so AR(p) is of order 6, MA(P) is also of order 6, so the value of p and q are all equal to 6.

4.4. ARMA-GARCHX Estimation Results

To better forecast the variance of future semiconductor returns, the ARCH model is next used to look at the characteristics of TSMC return volatility. And the consequences are shown in Figure 5.

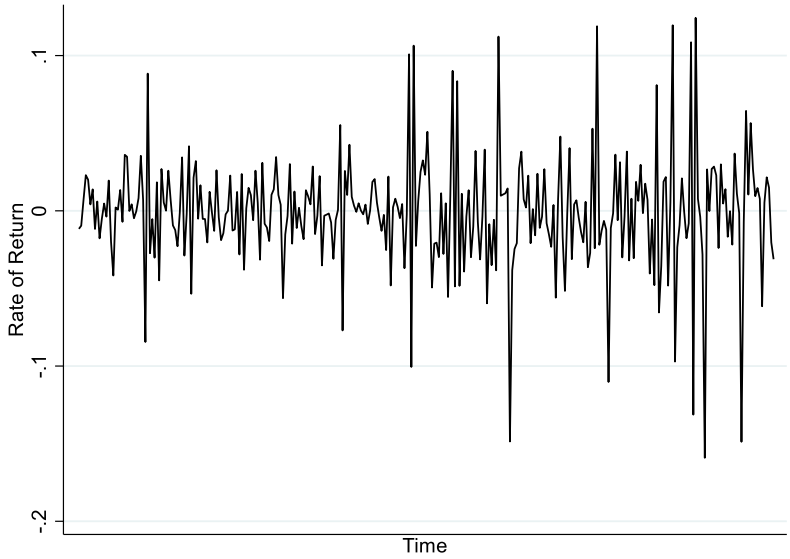

Figure 5. Yield (Photo credit: Original)

Looking at the images, there is a clear conditional heteroskedasticity in the two semiconductor indices, which is expressed in terms of returns fluctuating sharply at one time and less at another. This suggests, in terms of financial econometrics, that when volatility (variance) is higher in the present period or a few prior periods, it is likely that volatility (variance) will also be higher in subsequent periods, and vice versa. However, whether there is autoregressive conditional heteroskedasticity and how significant the conditional heteroskedasticity is still needed to be judged by the model estimation results.

From the time series diagram, TSMC returns show obvious aggregation, but whether this effect is statistically significant needs further empirical test.

Table 3. ARMA-GARCHX estimation results

	Coefficient	Std. err	z	p>|Z|
Mean equation				
AR, L1	0.5032	0.0687	7.3200	0.0000
MA, L1	-0.8899	0.0219	-40.6200	0.0000
Constant	-0.0001	0.0003	-0.4800	0.6350
Variance equation				
USD	99.1160	17.3342	5.7200	0.0000
ARCH, L1	0.3277	0.1308	2.5100	0.0120
GARCH, L1	0.4687	0.0925	5.0600	0.0000
Constant	-8.5299	0.2585	-33.0000	0.0000

From the estimation results of ARMA-GARCHX model (Table 3), ARCH term and GARCH term are significant at 5% and 1% levels, respectively, indicating that TSMC return rate has obvious conditional heteroscedastic property, which can be used for GARCH modeling.

From the estimation results of external explanatory variables, the dollar log return increases by 1 unit, TSMC volatility increases by 99.1160, and the coefficient is significant at 1% level.

5. Conclusion

The object of this thesis is to study how the TSMC affected by the Federal rate hike. The exchange rate's time points are added to the model as an explanatory variable and used to calculate results in this study. The association between the Federal interest rate increase and the returns and volatility of the TSMC stocks may thus be evaluated in this article.

Looking ahead, the Biden administration in the US is now focusing its policies on keep raising the interest rate of the US economy, indicating that the increase of TSMC stock will last for a long period of time. Thanks to the monopoly place of TSMC in the semiconductor sector, it is hard for TSMC to be affected by the negative effect of Federal rate hike. Therefore, to maintain its competitivity, TSMC needs to keep its advancing status in semiconductor industry so it can tide the company through difficult times.

References

[1] Irfan Akbar Kazi, Hakimzadi Wagan, Farhan Akbar. The changing international transmission of U.S. monetary policy shocks: Is there evidence of contagion effect on OECD countries[J]. Economic Modelling,2013,30.

[2] Li Tianguo. Research on transmission Mechanism of US exit from quantitative Easing to Emerging Economies -- an empirical analysis based on PVAR model [J]. International Economic Cooperation, 2014(10):86-91.

[3] Tan Xiaofen, Yin Wuxian, Dai Wei. Impact of US quantitative easing withdrawal announcement on emerging economies [J]. International Finance Research, 2016 (07):18-32.

[4] Sun Yan-lin, ZHANG Qian-Ting. Time-varying, Fed Rate Increase and China's Output: An Empirical analysis based on TVP-VAR model [J]. International Finance Research, 2016 (04):26-36.

[5] Xiao Weiguo, LAN Xiaomei. Research on spillover effects of a new round of Fed interest rate hikes on China's cross-border capital flows [J]. Economist, 2017 (02): 84-90.

[6] Vieira, F.V., Holland, M., da Silva, C.G., & Bottecchia, L.C. Growth and Exchange Rate Volatility: A Panel Data Analysis [J]. Applied Economics, 2013, 45(26): 3733-3741.

[7] Yang Changjiang, Zhou Jingdong. Real Exchange Rate Undervaluation and Economic growth: A literature review [J]. Journal of World Economy, 2014(11): 168-192.

[8] Eichengreen, B. The Real Exchange Rate and Economic Growth Studies, 2007, 56(4):7-20.

[9] Aizenman, J., & Lee. J. Real Exchange Rate, Mercantilism and Learning By Doing Externality [J]. Pac Econ Rev, 2010, 15(3):324-335.

[10] Mbaye, S. Currency Undervaluation and Growth: Is There a Productivity Channel? [J]. International Economics, 2013, 133:8-28.

[11] Rodrik, D. The Real Exchange Rate and Economic Growth [J]. Brookings Papers on Economic Activity, 2008(2):365-412.

[12] Bhalla, S. S. Economic Development and the Role of Currency Journal, 2008, 28(2):313-340.