

The Impact of Federal Reserve's Interest Rate Policy on US Semiconductor Industry

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Abstract. The Federal Reserve raised interest rates by 75BP in June. In the meantime, the American government has enacted laws and orders to promote the growth of the semiconductor sector [4]. The purpose of this essay is to assess how the Federal Reserve's interest rate policy has affected the US semiconductor industry. To determine whether it has a beneficial or negative impact on the industry, this research uses the VAR model. This study projects the yield and volatility of semiconductors using the ARMA-GARCH model. The findings demonstrate that raising interest rates encourages greater investment in the stock market, which is advantageous for the semiconductor sector. But as time passes, the yield's volatility rises as well. This paper provides the reason that since the US chip sector has long had a dominant position, chip demand is not price elastic, and the strengthening of the currency is insufficient to reduce chip demand. The outcome is dominated by net capital inflows.

Keywords: Semiconductor industry, Interest Rate, VAR Model, ARMA-GARCH-X Model.

1. Introduction

The Fed has gradually sped and increased the intensity of interest rate hikes since its initial increase in March [1]. So far, the Fed has raised interest rates by 25BP in March, 50BP in May, 75BP in June and 75BP in July [1]. It is easy to tell that it is speeding up. The consequence of it was a dramatic increase in the dollar index, which increased from 95.647 at the start of the year to a high of 109.479 at the end of August, a level that was almost 20 years ago, and an annual gain of as much as 13.34% by the end of August [1]. As a result, the Chinese yuan will lose value in relation to the dollar as the exchange rate between the two currencies rises [2].

The main reason of increasing the interest rate is to reduce the pressure of inflation. The United States is currently experiencing its highest level of inflation in the past 40 years, which has given the American market a slight jolt. The relevant figures show that in June 2022, the CPI in the US climbed by 9.1% year over year, setting a new high [3]. Additionally, it could increase employment and consumption, which will eventually benefit companies and develop the stock market.

Based on the foregoing theoretical analysis, it is difficult to determine how the semiconductor industry is being affected when the Federal Reserve System's decided to raise interest rates. As a result, an empirical test is required. This paper constructs VAR and ARMA-GARCHX model to evaluate the impact of the two influencing mechanisms as well as the yield and the volatility of the semiconductor industry.

The remaining sections are arranged as follows: Literature review is part two. It offers prior studies on the state of the semiconductor industry these days, with a particular emphasis on the post-pandemic period. The second section also discusses the current risks, including the lack of chips and the capital and resource shortages. Then it presents a related article that incorporates studies on monetary policy on the semiconductor industry as well as government policy, which likewise offers sensible solutions. The third section covers methodology and research design. It gathers specific data to build models. Additionally, it employs several models to assess the impact and return volatility. The findings of the empirical research in Part 4 demonstrate the second track's dominant advantage. In other words, the semiconductor business benefits from increased interest rates. After learning from the findings, this paper goes on to the discussion, which analyze the likely causes and what they represent for investors and policymakers. It ends by concluding.

2. Literature Review

The prior study focused on the post-pandemic semiconductor scarcity. They show how the needs of electronic gadgets, which have a high demand for chips, are impacted by global shutdowns [4] [5]. It demonstrates the growing significance of semiconductors in modern world development. From this vantage point, understanding semiconductor sector fluctuations is crucial to the electronic and investment markets.

Additionally, even though the demand for semiconductors is growing rapidly, most factories still underestimate it [5]. The disparity between the supply and demand for chips reveals the fragility of the supply chain and ecosystem supporting chip manufacturing [5]. As a result, factories must increase and speed up production. Investments are needed to buy the resources needed for the expansion. However, as the previous articles note, factories lack the funding. As a result, it is essential to know whether investing in semiconductors is a sensible move and how its value will change when subjected to external pressure.

Since the U.S. semiconductor sector is crucial on the international stage, the U.S. government is becoming increasingly concerned about the shortage and growing significance of semiconductors, which might have a considerable impact on national security. To enhance local semiconductor production, the U.S. is therefore implementing policy and legal changes. According to Voas, Kshetri and DeFranco, an executive order examining potential vulnerabilities in chip supply chains was published in February 2021. A measure called as the Creating Helpful Incentives to Produce Semiconductors for America Act (CHIPS Act) (H.R.7178) were launched in 2020. It intends to offer incentives to support enhanced R&D in the semiconductor industry and safer supply chains [4]. Considering the semiconductor sector seriously demonstrates how crucial it is. Therefore, assessing the effects of increased interest rates on it aids in analysis and future development forecasting. This is due to the major impact that rising interest rates have on the movement of capital and money. The entire semiconductor industry is actively looking for these. Evaluation of the consequences also allows one to determine whether there is disagreement regarding the orders and decisions made by the government and the Federal Reserve.

Wu et al. also undertake research on how the government's assistance to the semiconductor industry affected it in 2008 amid the financial crisis [6]. They learn that government assistance can boost the semiconductor business. According to their research, a reduction in interest rates would be favorable for South Korea since it would increase asset utilization. Therefore, from its standpoint, lowering interest rates can allow for an increase in market liquidity. The influx of cash boosts spending, which encourages the need for semiconductors. However, as money is gathered and flows into the stock market simultaneously, an increase in interest rates will also have a comparable effect. The difference impacts depend on the different researching background.

In general, study on the semiconductor industry focuses mostly on its history, such as COVID-19 and global shutdowns. Few researchers are trying to figure out the connection between the semiconductor business and studies on finance and monetary policy. Therefore, this paper fills in the research gaps about the impacts of the most recent Fed interest rate rise on semiconductor industry.

3. Research Design

3.1 Data Source

This study incorporates historical data on the semiconductor sector and currency market from Investing.com, a website that offers real-time information on the worldwide financial market. As for the currency market, this essay focuses on the exchange rate between the US dollar (USD) and the Chinese yuan (CNY), which shows how the US dollar fluctuated from June 2021 to August 2022 as a result of the Federal Reserve System's decision to raise interest rates. In terms of the semiconductor industry, this study seeks to find the closing price of the Philadelphia Semiconductor Index (SOX) throughout the same time period, which reflects the sector's corresponding fluctuations. These serve as the data foundation for researching how the decision may affect the semiconductor industry in the United States.

3.2 Unit Root Test

It is important to perform a unit root test as the time series model that cannot be built by using the data is not stable and smooth. Table 1 shows that the first log-returns' p-value is 0, which is less than 0.1, after utilizing the data to generate an ADF test in Stata. As a result, the original hypothesis can be rejected, indicating that the model is stable and smooth.

Table 1 ADF test

Variables	t-statistic	p-value
Price		
Semiconductor	-2.184	0.4987
Exchange rate	-0.926	0.9532
Index		
Semiconductor	-12.698	0.0000***
Exchange rate	-11.992	0.0000***

3.3 VAR model

This paper constructs VAR model, which is used to estimate the dynamic relationship of the log-return of Philadelphia semiconductor index and the log-return of the exchange rate between the US dollar (USD) and the Chinese yuan (CNY). As a result, it can generate the autoregression on several lagged variable to perform the current variable.

The model VAR(t) is set as follows:

$$X_t = \sum_{i=1}^{p} \prod_i X_{t-i} + U_t \tag{1}$$

In equation (1) above, X_t is a column vector of a $N \times 1$ time series. U_t is a column vector of the random error. The subscript t indicates that the variable changes over time.

The VAR model's construction has no restrictions on the variables and is not based on any economic theory. The estimation and projection processes benefit from the exclusion of all current variables. Additionally, Eltony and Al-Awardi employ the VAR model to assess how oil price fluctuations affect Kuwait's macroeconomic indicators, which indicates the significance of the VAR model [7].

But in addition to the number of interdependent variables, its construction also needs k, the number of lagged variables that can account for the interdependent endogenous variables. If k is too small, the error term will have an autocorrelation issue, which could result in an excessive amount of error while estimating the model parameters. The model's degrees of freedom will shrink if k is too high, which will negatively impact the model parameter estimator's performance.

Hatemi-J et al. has proved that using the LR test in addition to SBC and HQC significantly improves the likelihood of selecting the best lag order when compared to scenarios when just SBC or HQC are employed, according to the results of Monte Carlo simulations [8]. The underlying model's capacity for predicting tends to improve as a result of this improvement in lag order selection [8]. The calculation of k is based on LR likelihood method, which is defined as follows:

$$LR = -2(LogL_k - LogL_{k+1}) \tag{2}$$

$$LR \sim X^2_{(N^2)} \tag{3}$$

In the equation (2), k, the lag order of the VAR model is regarded as moderate when the LR statistic is lower than the critical value. The lag order of the VAR model is thought to be insufficient when the LR statistic is higher than the critical value, and extra lagged variables should be included as explanatory variables.

Another method, AIC statistics is as follows:

$$AIC = \log\left[\frac{\sum_{t=1}^{T} e_t^2}{T}\right] + \frac{2k}{T} \tag{4}$$

$$min_k\{AIC\} = \log\left[\frac{\sum_{t=1}^{T} e_{kt}^2}{\sum_{t=1}^{T} e_{(k+1)t}^2}\right] - \frac{2}{T} \tag{5}$$

According to equation (5), k is more appropriately valued if the ratio of two AIC models with lag orders of k and k+1 is smaller.

After the VAR model is constructed, it is essential to test whether it is stable. Its necessary and sufficient condition is that all eigenvalues value of the coefficient matrix fall within the unit circle.

Additionally, applying impulse response function into the analysis could help describe the response of endogenous variables to the change of error terms in the VAR model.

$$\frac{\partial y_{t+s}}{\partial \varepsilon_t'} = \psi_s \tag{6}$$

From the equation (6) above, the subscript t means period t and the subscript s stands for the time interval. It shows the impact on the value $y_{i,t+s}$ of the i-th variable in period t+s, when the perturbation term ε_{jt} of the j-th variable in period t is increased by 1 unit and the other variables are unchanged from the perturbation terms in other periods.

3.4 ARMA-GARCH model

The ARMA-GARCH model is used in this study to forecast semiconductor volatility since Liu and Shi have demonstrated how crucial it is for predicting short-term electricity prices [9].

Firstly, this paper constructs an ARMA (p, q) model as follow:

$$x_t = \phi_0 + \sum_{i=1}^{p} \phi_i x_{t-i} + a_i - \sum_{i=1}^{q} \phi_i a_{t-i} \tag{7}$$

In the equation (7), AR(p) is presented as $\phi_0 + \sum_{i=1}^{p} \phi_i x_{t-i}$ while MA(q) is shown as $a_i - \sum_{i=1}^{q} \phi_i a_{t-i}$. The AR(p) model uses historical data on the SOX closing price to forecast future realized value. The MA(q) model uses past perturbations to predict the future.

To select the order of ARMA model, this part use the PACF method to select the order for the AR model and apply the ACF method to select the order foe the MA model.

After constructing the ARMA model, this part need to construct the GARCH (p, q) model.

$$\sigma_t^2 = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \cdots + \alpha_q\varepsilon_{1-q}^2 + \gamma_1\sigma_{t-1}^2 + \cdots + \gamma_p\sigma_{1-p}^2 \tag{8}$$

In the equation (8), $\alpha_1\varepsilon_{t-1}^2 + \cdots + \alpha_q\varepsilon_{1-q}^2$ is the ARCH part while $\gamma_1\sigma_{t-1}^2 + \cdots + \gamma_p\sigma_{1-p}^2$ is the GARCH part. In the ARCH part, the subscript t indicates that the conditional variance of the disturbance term ε_t, σ_t^2, varies over time. In the GARCH part, the square of the disturbance term over the past p periods determines how σ_t^2 will behave. Generally, constructing the GARCH model helps predict the volatility of the semiconductor industry. The function is constructed as follow.

$$\sigma_t^2 = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \gamma_1\sigma_{t-1}^2 + \beta_1 D_t + \beta_2 D_{t-1} + \beta_3 D_{t-2} \tag{9}$$

4. Results and Analysis

4.1 VAR Order Selection

As for constructing the VAR model, the initial thing is to order the log-returns of it. The result is as below.

Table 2 VAR model identification

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	1994.78				2.4e-09*	-14.1835*	-14.1731*	-14.1576*
1	1988.67	7.7725	4	0.100	2.4e-09	-14.1827	-14.1515	-14.105
2	1998.92	.5045	4	0.973	2.4e-09	-14.156	-14.1041	-14.0265
3	2001.72	5.6016	4	0.231	2.5e-09	-14.1475	-14.0748	-13.9662
4	2005.02	6.5946	4	0.159	2.5e-09	-14.1425	-14.049	-13.9094
5	2005.7	1.3517	4	0.853	2.5e-09	-14.1188	-14.0046	-13.834
6	2007.15	2.9133	4	0.572	2.6e-09	-14.1007	-13.9657	-13.7641
7	2008.35	2.387	4	0.665	2.6e-09	-14.0807	-13.925	-13.6923
8	2011.82	6.9492	4	0.139	2.6e-09	-14.077	-13.9005	-13.6368
9	2016.52	9.4094	4	0.052	2.6e-09	-14.082	-13.8847	-13.59
10	2020.84	8.6364	4	0.071	2.6e-09	-14.0843	-13.8662	-13.5405
11	2021.98	2.2648	4	0.687	2.7e-09	-14.0639	-13.825	-13.4683
12	2024.27	4.5926	4	0.332	2.7e-09	-14.0518	-13.7921	-13.4044

From Table 2, by studying the results of LR, VAR is of order 9. To test if the VAR model is stable, this part thus draw the picture below to tell if every value falls into the unit circle.

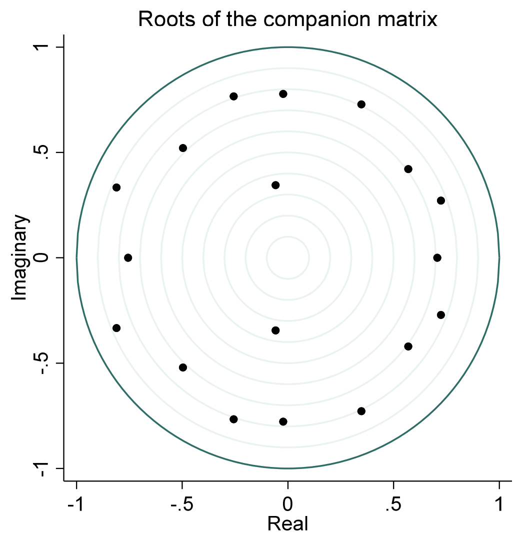

Figure 1 Unit root test

Note: The X-axis is the real number, and the Y-axis is the imaginary number. The circle is bounded by its radius, 1.

It can be observed from Figure 1 that the VAR model is stable and smooth based on the results of the unit root test. It is therefore of order 9.

4.2 Impulse Response

Further, this part apply the impulse response function to the VAR model to better see the impact of raising interest rate on the semiconductor industry.

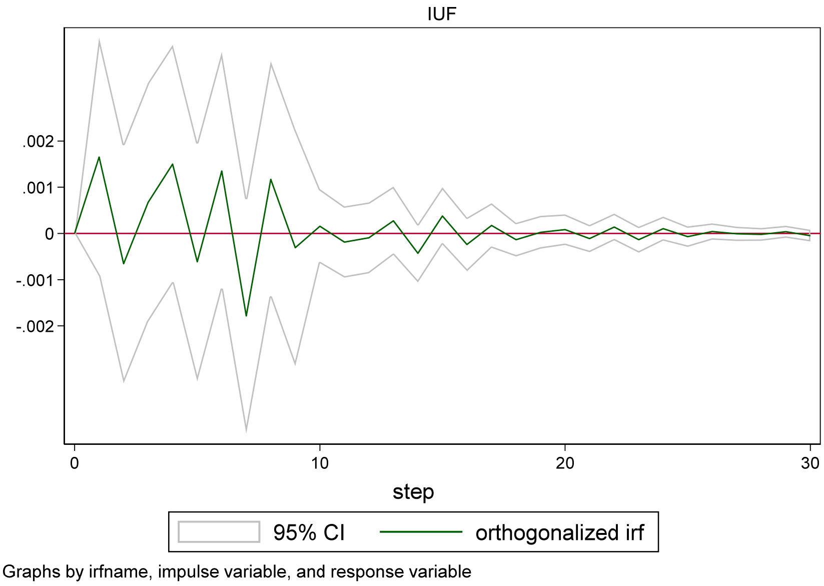

Figure 2 Impulse and response

Starting from March 2022, the Federal Reserve announced hiking the interest rate. Theoretically, it is certain that it will enhance demand for dollars on the global floating capital and financial markets, which will further increase the exchange rate. However, the effects of a higher exchange rate on the American semiconductor industry can lead to economic consequences as follows.

First, according to the producer theory of microeconomics, this part could make a weak assumption, namely that firms' product prices are stiff in the short term, making it challenging for firms to adjust their prices in response to exchange rates in the near term. Because semiconductor industry is an export-dependent business in the United States, Chip sales and financial reports are both measured in U.S. dollars. So, a Fed rate increase could be bad for the semiconductor industry to the degree that a stronger currency means businesses make less money abroad. Furthermore, rising interest rates will inevitably encourage domestic saving and deter consumption, which is another unfavorable aspect.

Second, more dollars are available on the global financial market, which could raise demand for stocks by moving into the stock or bond markets. In other words, the American stock market is experiencing a net inflow of cash, which might raise stock prices there.

According to estimated impulse response results (Figure 2), the net effect of the dollar's rise on the chip industry is favorable. So, the second channel, that the U.S. stock price is driven up with a net inflow of the capital into the stock market, is dominating. Specifically, period t=1 occurs the largest net effect of a one-unit exchange rate shock on the chip industry in period t=0, with a size of slightly less than 0.2%. And period t=4 has the second-largest value, with a size of roughly 0.15%. Notwithstanding a few periods net effects that are negatively skewed, the exchange rate shock has a beneficial net effect on the US semiconductor industry generally, which indicates that capital inflows predominating it.

4.3 ARMA Order Selection

To construct the ARMA-GARCH model, it is essential to respectively select orders for AR(p) and MA(q) models. The results are shown as follows.

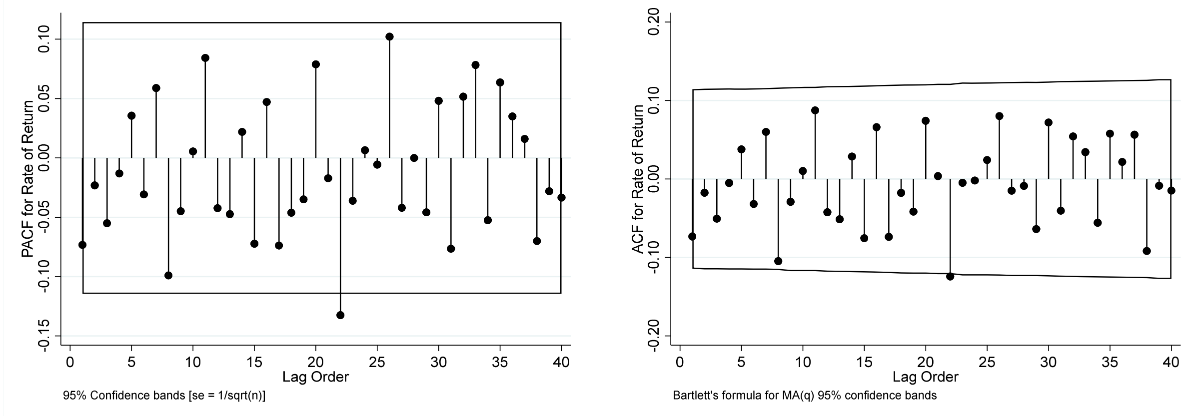

Figure 3 PACF and ACF

Notes: The X-axis represents for the lag order while the Y-axis stands for the rate of log-return. The 95% confidence interval for AR(p) and MA(q) is the region between y=±2 standard error.

As seen in Figure 3, the left graph's first point beyond the X-axis is 22, while the right graph's first point beyond the X-axis is 22. The MA(q) is also of order 22, and the AR(p) is of order 22 as a result. In other terms, p = 22 and q = 22.

4.4 ARMA-GARCH Estimation Result

After selecting the order of ARMA, this part could use ARMA-GARCH to forecast the future yield and volatility. The results are as follows.

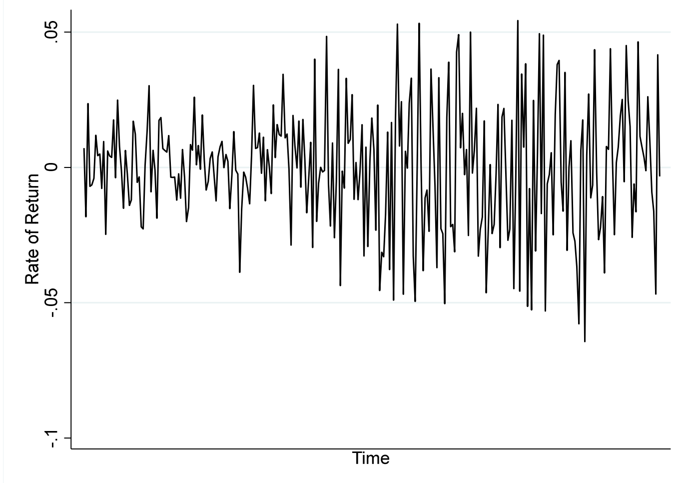

Figure 4 Yield

The time series diagram (Figure 4) clearly shows that the volatility of returns in the semiconductor industry rises over time and that there is a rather visible clustering, but further empirical research is still needed to determine whether this effect is meaningful.

Table 3 ARMA-GARCHX estimation results

	(1)		(2)		(3)	
	Coefficient	p>|Z|	Coefficient	p>|Z|	Coefficient	p>|Z|
Mean equation						
AR, L22	0.7608	0.013	0.7834	0.010	0.8502	0.001
MA, L22	-0.8479	0.002	-0.8682	0.001	0.7593	0.008
Constant	0.0004	0.586	0.0004	0.600	0.0005	0.589
Variance equation						
Exchange rate						
L0	394.5297**	0.022	315.4484	0.666	239.1036	0.849
L1			200.3615	0.849	186.9613	0.909

L2					100.4536	0.953
GARCH (1, 1)						
ARCH, L1	0.0772**	0.047	0.0781**	0.047	0.0714**	0.048
GARCH, L1	0.9045***	0.000	0.9035***	0.000	0.9127***	0.000
Constant	-11.9539***	0.000	-11.9072***	0.000	-11.9536***	0.000

According to the estimation results of the ARMA-GARCHX model (Table 3), the return rate of the semiconductor sector has statistically significant ARCH and GARCH effects, both of which are significant at least at the 5% level. In light of this, GARCH modeling is possible. The results in column (1) from the estimate of external explanatory factors demonstrate that the volatility of the semiconductor sector increases by 394.5297 units when the logarithmic return rate of exchange rate increases by 1 unit in period t=0, and the coefficient is significant at the 5% level. The coefficient of log return on exchange rate, however, is no longer significant after the lag value is included in the model in columns (2) and (3), showing that there is no lag effect of exchange rate change on volatility.

5. Discussion

Contrary to Feldstein's idea that increasing the interest rate can avoid the situation that the price of stocks rises to unsupportable heights due to portfolio investors [10], the result shows that hiking interest rate boosts the inflow of the capital into the stock market, which hence rise the yield of semiconductor industry. One possible reason for the result is that the US semiconductor sector has long held a monopolistic position. The position is even strengthened due to the global shortage of chips and the protective policy introduced by the U.S. government. Because of this, the demand for chips is not price elastic, and an increase in the value of the US dollar is insufficient to reduce this demand. Net capital inflows therefore dominate the outcome. It is significant because instead of projecting the consequence from the starting point, taking the characteristics of the receivers into the consideration is also essential as it may lead the thing to an opposite way.

For the decision-makers, the outcome suggests that raising interest rates is advantageous for the growth of the sector. There is therefore often no conflict between raising interest rates and encouraging the development of However, it is crucial to take into account its risk, which includes the greater return volatility and the potential market disruption brought on by the significant capital input. Before encountering the significant fluctuation, the policymakers are needed to create strategies. Investors may consider investing in the semiconductor business because rising interest rates have a favorable effect on its returns, which is also consistent with policy. However, it is crucial to carefully consider its volatility, which will grow over time, and balance the advantages and disadvantages.

6. Conclusion

In March 2022, Fed hikes interest rate since March and has raised it by 75BP in June. Additionally, the U.S. government pays great attention to the semiconductor industry. It is significant to research whether the fluctuation of interest rate would affect the development of semiconductor industry. So, this paper uses VAR and ARMA-GARCH model to evaluate the impact and predict semiconductor's yield and volatility. In conclusion, the absence of price elasticity in the chip demand is directly related to the long-term monopoly of the American chip sector. Therefore, the dollar's increase is insufficient to reduce the demand for chips. The demand for equities will rise as a result of the increased dollar liquidity in the worldwide financial market as a result of the Federal Reserve's interest rate increases. The American stock market has, in other words, received a net influx of capital. As a result, American share prices gradually increased, which allowed net capital inflows to dominate the outcome. In addition, it is discovered that there is no lag effect of exchange rate fluctuations on volatility and that the volatility of returns in the chip business clearly increases over time. In the future, it will be vital to look more closely at the specific causes and circumstances of the volatility.

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