

The Long-term Relationship between USD to CNY Exchange rate and China's Semiconductor: An Empirical Research

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Abstract. As a fast-growing industry, semiconductors have gradually become a necessity in the modern world. In addition to its economic importance, the semiconductor industry is closely linked to national and social security. Modern national security largely depends on the level of science and technology, and the level of science and technology in the semiconductor industry plays a decisive role, so the development of the chip industry determines a country's national security and military status to a large extent. China, now the world's second largest economy, is also aggressively developing its semiconductor industry. Meanwhile, the import and export of the semiconductor industry is largely affected by the exchange rate between China and the United States. In this paper, China's semiconductor index from January 1994 to September 2022 and the USD to RMB exchange rate from January 1994 to present are extracted. The VAR model was applied in the study to evaluate the link between variables, and the ARMA-GARCH model was used to determine and analyze both earning ability and stock volatility throughout these years. The study predicts the future development direction of Chinese semiconductor industry and provides investment recommendations to its stakeholders.

Keywords: China, Semiconductor industry, Exchange rate, ARMA-GARCH model.

1. Introduction

On September 21, 2022, the Federal Reserve officially announced that it was raising the target range for its policy rate, the federal funds rate, from 2.25% to 2.5% to 3% to 3.25%, the highest level since early 2008. It was the Fed's third consecutive increase of 75 basis points this year and its fifth rate hike since 2022, marking the most intensive pace of rate hikes since the 1980s. In the short term, the Fed's tightening monetary policy will not change, the interest rate policy will still support the dollar index. On the September 15, 2022, the offshore CNY exchange rate fell below 7 to the US dollar. It was also the first time since August 2020 that the offshore yuan broke 7 against the dollar. The root cause of the RMB's sharp depreciation is the appreciation of the US dollar, which has been rising strongly since March 2022, when the United States decided to raise the interest rate to curb inflation. After the United States raised interest rates, bond yields in the United States rapid rise, therefore, the risk-free rate in the United States rise, and global capital aim to earn money. When the United States, the world's biggest pool of significantly higher risk-free rates, is bound to attract global capital return to the United States, the dollar is naturally going up.

While the change in CNY and USD exchange rate will influence many industries in China. As the core of the information technology industry, the semiconductor industry is an important foundation for all walks of life to realize the development of information and intelligence and is a vane of global economic recovery. China and the United States are the world's largest demander and supplier of semiconductor products. The United States still leads the world in semiconductor chip. However, with the effects of the trade war between China and the United States, and under the policy of the Chinese government to encourage the localization of the semiconductor industry, the local semiconductor material manufacturers have been continuously improving the technical level and Research & Development capability of semiconductor products. China gradually broke the monopoly pattern of foreign semiconductor manufacturers and promoted the localization process of China's semiconductor materials.

China's semiconductor market has grown rapidly over the past 10 years, but it is also subject to US restrictions on advanced technologies and related companies, including export controls, investment restrictions, and other financial regulations. The Chip and Science Art of 2022 aims to revitalize domestic semiconductor manufacturing and invest in science to ensure US leadership, reduce US dependence on foreign sources of semiconductors, and strengthen US national security. In the future, Chinese enterprises may be affected to varying degrees in terms of participating in manufacturing plans in the US, obtaining funding from the US, and introducing external talents. After the promulgation of this law, China will be further forced to accelerate the establishment of an independent and controllable semiconductor ecosystem and supply chain, and increase policy guidance and financial support for the semiconductor industry. As the world's main chip consumer market, China has ushered in an excellent turnaround in independent research and development.

The rest of this paper is organized as follows: the second part is the literature review, which includes relevant research on the causes and impacts of the USD to CNY exchange rate and how the exchange rate has brought about changes in the semiconductor industry in each of the two countries, concluding with a summary of the literature review. Then it is followed by Part 3, which uses certain data and images as an aid and focuses on the impact of the US-China exchange rate on the semiconductor industry and illustrates the impact of the exchange rate on the semiconductor industry in China and the world at large from various perspectives. After that, the fourth section will then conduct an ARMA-GARCH model analysis using the relevant data obtained. The results of empirical analysis used to demonstrate results of the empirical analysis are used to demonstrate the impact of the exchange rate change and a series of impacts on Chinese semiconductor companies, and finally to draw conclusions and make predictions and give feasible and innovative suggestions for the future development of the USD to CNY exchange rate and Chinese semiconductor industry.

2. Literature Review

2.1. China's Foreign Trade Condition and Semiconductor Industry

After China's reform and opening in 1978, China's economic growth and foreign trade have both grown extraordinarily rapidly. According to the 'Summary and Analysis of Foreign Trade Import and Export Statistics from January to December 2021' published by the China Institute of Foreign Economic and Trade Statistics. In 2021, China's import and export volume reached \$6,051.49 billion, up from 2020 by 30.2% longer; Among them, the total export volume was 3,363.96 billion US dollars, up 29.9% year on year; Imports totaled \$2,687.53 billion, year-on-year Growth of 30.1%. This shows that import and export is a crucial component of China's economic growth. China is becoming the greatest producer of electronics in the world thanks to the country's growing economy [1], and China has still relied heavily on foreign countries' critical technologies [1]. The import of technology is common for China's techno-industrial development [2]. However, Semiconductors are at the heart of the US-China technology hegemony competition under the administration of U.S. President Joe Biden [3], the conflicts between China and US made China's semiconductor industry in a tough situation. Consequently, the creation of a domestic semiconductor supply chain is crucial for China's future prosperity [1].

2.2. Economic Consequence of Change in the Exchange Rate

Exchange rate, as a vital part of trade between countries, has had a series impact on China and is one of the most crucial relative prices in terms of the macroeconomic [4]. Exchange rate is also a critical factor which links capital flow and international trade. China has been transitioning from a managed exchange rate to a totally floating exchange rate during the past twenty years [5]. How will the exchange rate influence international trading? If the economy is uncompetitive and in recession, a falling exchange rate can be helpful. A weaker currency results in increase in export demand and vacancy. Inflation is not a problem during recession. In good times, however, devaluation can lead to inflation. In addition, a weaker currency lowers living standards as imported goods become more

expensive. Exchange rate appreciation is helpful if it is the result of a more productive and competitive economy. However, if speculation leads to an appreciation of the RMB, then exporters will not be able to compete, which is harmful. Washington has long worried that if China continues to keep the exchange rate of RMB artificially low, the RMB will become stronger than the dollar given the strength of the Chinese economy [6]. According to the research of Parsley and Popper, businesses in the Asia-Pacific region were more vulnerable to the risk of currency changes, particularly dollar swings, than those in western industrialized nations [7]. Chinese economic channels, on the other hand, are strong and can transfer exchange rate risk exposure to equities market risk premiums. Including robust international trade, regular domestic credit expansion, and cross-border capital flows [8]. Furthermore, The Chinese government has kept a tight grip on the value of the currency to control money flowing in and out of the country and to obtain a favorable exchange rate to help stimulate exports and manufacturing [9].

In summary, it is a basic fact that China's economy has long depended on imports and exports, especially its semiconductor industry. However, as the United States further imposed sanctions, China's semiconductor industry is moving toward localization reform. However, this reform must be a long-term behavior, in today's global environment, the import and export of semiconductor industry are inevitable. As an important factor affecting import and export, the exchange rate also has a crucial impact on China's semiconductor industry. This paper will conduct further analysis based on the development of China's semiconductor industry and the exchange rate change between RMB and the US dollar, so as to analyze and summarize the correlation between the two according to China's specific policies and the world economic environment.

3. Research Design

3.1. Data Source

This paper uses the Choice financial terminal [10], a search engine, in conjunction with Yahoo Finance [11] to search and obtain data on the semiconductor industry, to find out the China's semiconductor index from January 1994 to September 2022 and the USD to CNY exchange rate from January 1994 to present, as a data source and data basis for empirical analysis to study the impact of the USD to CNY exchange rate on China's semiconductor industry.

3.2. Augmented Dickey–Fuller (ADF) Unit Root Test

After completing the model construction, this part first needs to perform a unit root test (smoothness test) on the model to test whether the data is stationary, where the null hypothesis is that this time series is not smooth. Data were input into Stata for ADF test. As can be seen from Table 1, the p-value of log-returns is 0, less than 0.1, which can reject the null hypothesis that the model is stable and feasible.

Table 1. ADF test

Variables	t-statistic	p-value
Price		
Semiconductor	-3.055	0.1173
Exchange rate	-1.661	0.7676
Yield		
Semiconductor	-34.789	0.0000
Exchange rate	-34.609	0.0000***

3.3. Vector Autoregression (VAR) Model

VAR models are usually used to estimate the dynamic relationship of joint endogenous variables. It is realized by using all current period variables in the model to perform autoregression on several period lag variables of all variables. The advantage of VAR model is that this model can explain

causality between multiple variables in the past and over time, as well as predict future observations. Interpretation and prediction of future observations in time series depend on correct assumptions about the VAR model and estimation of its parameters [12].

$$S_t = \alpha_{10} + \alpha_{11}S_{t-1} + \dots + \alpha_{1p}S_{t-p} + \beta_{11}ER_{t-1} + \dots + \beta_{1p}ER_{t-p} + \epsilon_{1t} \quad (1)$$

$$ER_t = \alpha_{20} + \alpha_{21}S_{t-1} + \dots + \alpha_{2p}S_{t-p} + \beta_{21}ER_{t-1} + \dots + \beta_{2p}ER_{t-p} + \epsilon_{2t} \quad (2)$$

The equations are for semiconductor index and USD-CNY exchange rate respectively. In equation (1), $\alpha_{10} + \alpha_{11}S_{t-1} + \dots + \alpha_{1p}S_{t-p}$ represent the linear function of past lags of semiconductor index, meanwhile $\beta_{11}ER_{t-1} + \dots + \beta_{1p}ER_{t-p}$ represents past lags of USD to CNY exchange rate, ϵ_{1t} represents the error term. Overall, the variable semiconductor index is modelled using historical value of the variable itself and the past value of USD to CNY exchange rate. The model of USD to CNY exchange rate has the similar equation with the semiconductor, the change is in the variable on the left side of the equation and coefficients on the right side.

3.4. ARMA-GARCH Model

The ARMA-GARCH model can evaluate both the return and volatility of the semiconductor index. This model is broken down into two sections in this paper: ARMA and GARCH.

3.4.1 ARMA

$$x_t = \phi_0 + \sum_{i=1}^p \phi_i x_{t-i} + a_t - \sum_{i=1}^q \theta_i a_{t-i} \quad (3)$$

The equation (3) is the general expression of ARMA model. The AR(p) is represented by the component $\phi_0 + \sum_{i=1}^p \phi_i x_{t-i}$, while MA(q) is represented by $a_t - \sum_{i=1}^q \theta_i a_{t-i}$. AR(p) applies the historical value of semiconductor index from 1994 to 2022 to predict the future value, while the MA model uses an error term to forecast the future.

3.4.2 GARCH

Another section is GARCH, GARCH model is set up based on the ARCH model. The models condition on heteroskedasticity to keep track of and manage changing volatility [13]. In this paper, GARCH (1, 1) was applied to evaluate the volatility.

$$\sigma^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2 + r_1 ER_t \quad (4)$$

$$\sigma^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2 + r_2 ERS_t \quad (5)$$

In the equation (4) and equation (5), α_0 is constant, $\alpha_1 \varepsilon_{t-1}^2$ is ARCH part, $\beta_1 \sigma_{t-1}^2$ is GARCH part, $r_1 ER_t$ and $r_2 ERS_t$ represent parts for ER and ER sigma-sq respectively.

4. Empirical Results and Analysis

4.1. Order of VAR Model

To find out the optimal lag order for a VAR model, the LR statistic and other information criterion of each lag should be assessed. An asterisk sign (*) appears after the data to indicate the desired lag order.

Table 2. VAR model identification

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	19455				1.8e-09	-14.4632	-14.4616	-14.4588
1	19474.4	38.909	4	0.000	1.8e-09*	-14.4747*	-14.4699	-14.4615
2	19477.2	5.5777	4	0.233	1.8e-09	-14.4738	-14.4658	-14.4518
3	19479	3.5872	4	0.465	1.8e-09	-14.4721	-14.4461	-14.4414
4	19480.4	2.7286	4	0.604	1.8e-09	-14.4702	-14.4559	-14.4307
5	19485.2	9.5827	4	0.048	1.8e-09	-14.4708	-14.4533	-14.4225
6	19486.1	1.9323	4	0.748	1.8e-09	-14.4685	-14.4479	-14.4115
7	19487.2	2.1364	4	0.711	1.8e-09	-14.4663	-14.4425	-14.4006
8	19488.8	3.1455	4	0.534	1.8e-09	-14.4645	-14.4376	-14.39
9	19491.3	5.1377	4	0.273	1.8e-09	-14.4635	-14.4333	-14.3801
10	19497.7	12.726*	4	0.013	1.8e-09	-14.4652	-14.4319	-14.3731
11	19500	4.4908	4	0.344	1.8e-09	-14.4639	-14.4274	-14.3631
12	19501.2	2.4242	4	0.658	1.8e-09	-14.4618	-14.4222	-14.3522

Table 2 shows that lags 1, 2, and 10 all have this symbol. To determine the optimal lag order, AIC differences need to be compared. The difference in AIC between lags 10 and 11 is about 0.002, while the difference between lags 1 and 2 is about 0.001. Therefore, delay 1 is a better choice to start with. In addition, although both FPE and AIC with asterisks are minimized at lag 1, and HQIC and SBIC imply other alternative orders, the present optimal lag order of the VAR model should be 1.

Following the specification of the VAR model's order, it is crucial to examine whether the VAR model is stationary. If the VAR model is non-stationary, the impulse-response function will not converge to zero, indicating that USD to RMB exchange rate have long lasting effects on the China semiconductor index. After that, the model's applicability was determined by carrying out the unit root test and sketching a unit circle with the roots. All the roots are clearly within the circle in Figure 1, implying that there is no need to reevaluate the lag order and that triradiate VAR (10) is a stable model.

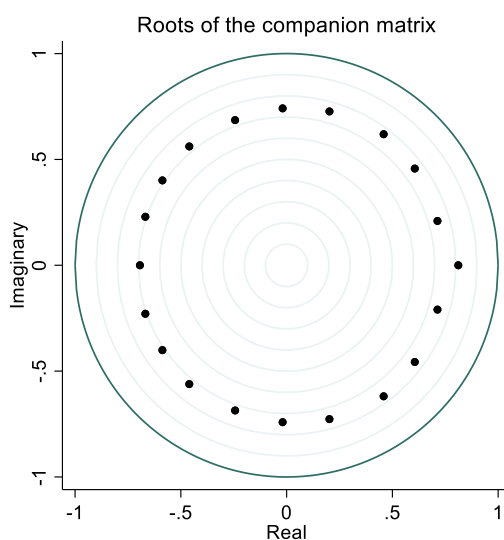


Figure 1. VAR stability

Photo credit: Original

4.2. Impulse Response

The increase of the exchange rate of US dollar against RMB means the appreciation of US dollar, which will cause capital flow. The international capital market and international floating capital will increase their holdings of US dollar due to the interest factor. Dollar against the yuan appreciation

could lead to economic results as follows: first, the international capital for the dollar's increase is likely to make large amounts of dollars flowing into the U.S. stock market or the bond market, the behavior means that the US capital inflows, similarly, the Chinese capital outflows. The immediate economic consequence of this action is to raise (lower) the share price or yield of the US (China) stock market; Second, the dollar means that purchasing power increases, so will boost America's imports, restrain exports of US companies, and promote China's export, curb China's imports. Chips are a highly international industry, which would obviously boost the interests of China's homegrown chip companies. From theoretical analysis can't get the influence of the capital outflow effect or export effect is predominant advantages, and the effects of the two kinds of dominant situation may also appear alternately.

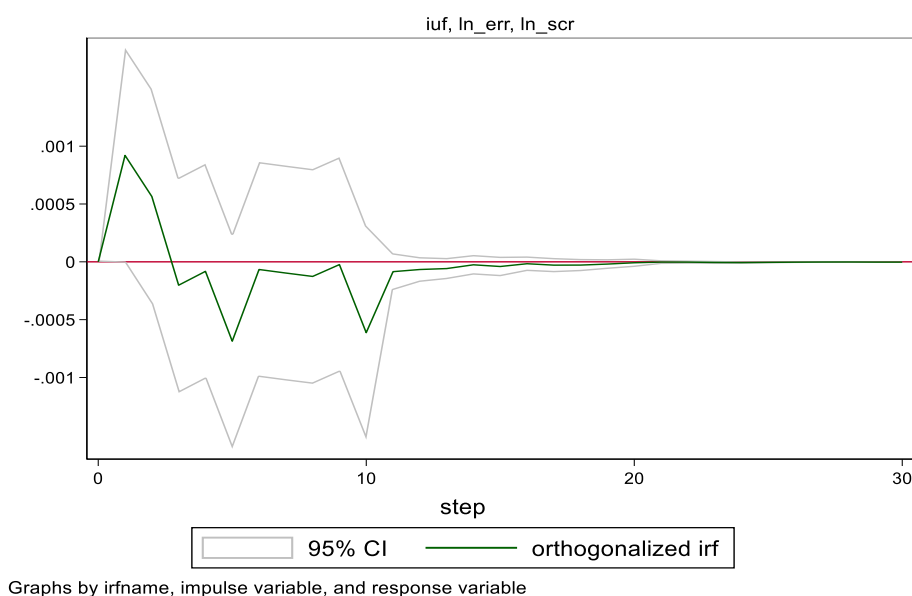


Figure 2. Impulse and response

Photo credit: Original

According to the estimation results of impulse response, Figure 2 shows that the exchange rate shock of one unit in period $t=0$ has a positive impact on the return rate of China's semiconductor industry in the next three periods, that is, the export dominates the effect. The largest positive effect occurs in period $t=1$, at just under 0.1%. After period $t=4$, the net capital outflow began to dominate, and the increase in the exchange rate (i.e., the appreciation of the USD) harmed the return rate of Chinese semiconductor industry. The shock of the current period gradually disappears after the 10th period. Can be concluded from the above analysis, the dollar net impact on China's semiconductor industry is time-varying and is not a simple export effect or dominant net capital outflow.

4.3. ARMA Specification

Regarding the order of the stock return in logarithm, PACF and ACF can be helpful to derive the lag orders for $AR(p)$ and $MA(q)$. In Figure 3, for semiconductor, the first part beyond the critical values is 1 for both PACF and ACF plots, demonstrating that $AR(p)$ and $MA(q)$ both have order 1 and value of p and q are equal to 1. For exchange rate, the first part beyond the critical values is also 1 for both PACF and ACF plots, demonstrating that $AR(p)$ and $MA(q)$ both have order 1 and value of p and q are equal to 1.

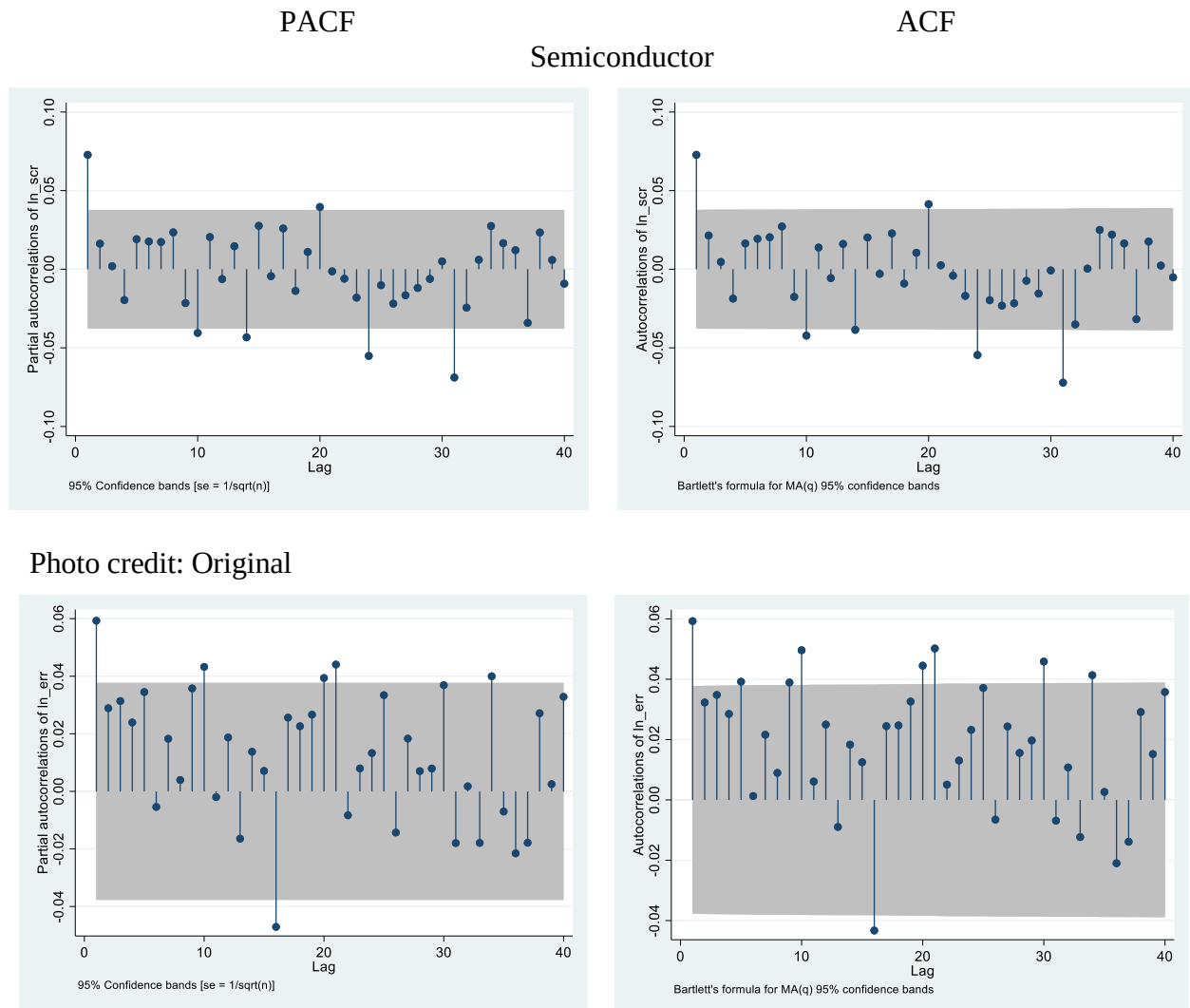


Figure 3. PACF and ACF

4.4. ARMA-GARCH Estimation Results and Variance Equation

Table 3. ARMA-GARCHX estimation results

Variables	(1)			(2)		
	Coefficient	Std. err	$p > Z $	Coefficient	Std. err	$p > Z $
Mean equation						
AR, L1	.2019624	.3970424	0.611	.2078867	.395935	0.600
MA, L1	-.1577019	.4003965	0.694	-.1636596	.3994293	0.682
Constant	.0003133	.0004407	0.477	.0003268	.0004473	0.465
Variance equation						
ER	-201.5445	132.0859	0.127			
ER, sigma-sq				-6.90504	7.195508	0.337
GARCH (1, 1)						
ARCH, L1	.0475522	.0054899	0.000	.0461773	.0052717	0.000
GARCH, L1	.9438042	.0061005	0.000	.9458897	.005805	0.000
Constant	-12.25755	.2192607	0.000	12.10763	.2539566	0.000

In order to study the spillover effect of exchange rate changes, this paper uses the logarithmic rate of return to build an ARCH model and extracts the volatility of exchange rate. From Table 3 ARMA - GARCHX model estimation results, the first column (1) and (2) the list of the ARCH and GARCH

coefficients at 1% significance level, indicates that China's semiconductor index statistically significant conditional heteroscedasticity, meet the basic conditions of GARCH modeling. Paragraph (1) and (2) column model of the external variable logarithm yield of exchange rate and exchange rate volatility, respectively, can be seen from the coefficient of the two, both yield and volatility, volatility on China's semiconductor industry earnings were not significant effect. Therefore, combining with the pulse response of the above diagram, this paper argues that in the long run, exchange rate changes lead to changes in the semiconductor industry yields, but did not lead to volatility.

5. Discussion

In comparison of other studies, this paper focus on how long-run changes in CNY and USD exchange rate will affect the semiconductor index in China, whereas existing articles focus on China's semiconductor industry based on the impacts on US sanction and Chinese semiconductor localization. Although some articles investigate exchange rate's effects on China foreign business, their topics are more related to oil, tourism, Bitcoin, and so on. However, one similarity between us is in analyzing stock market volatility is that many authors adopted methodology or related transformations such as VAR model, GARCH model, or others in their research to determine stock market movements. Through this paper, investors could pay more attention to short term changes of exchange rate between CNY and USD, as the appreciation of the dollar against the yuan has a negative correlation with the yield of China's semiconductor industry. The net impact of dollar appreciation on China's semiconductor industry is time-varying and is not dominated by pure export effect or net capital outflow. In the long run, exchange rate changes have led to changes in semiconductor returns, but not to higher volatility. According to the findings of this study, it is important for investors who are concerned about semiconductor stocks to forecast the exchange rate fluctuation and the political impacts on Chinese semiconductor industry. Therefore, investors need keep an eye on the latest news in order to modify their short-term investment strategies.

6. Conclusion

The objective of this study is to investigate how long-term USD to CNY exchange rate correlate to the semiconductor industry combined with analysis of latest news include US sanction, Chinese semiconductor localization process, Chinese exchange rate policies, and so on. VAR and ARMA-GARCH models are introduced for this purpose, with the VAR model exploring impulse response and the ARMA-GARCH model assessing stock returns and conditional variances. The study leads to a conclusion after conducting empirical investigation.

Finally, this article demonstrates that long-term exchange rate variation does not have significant effect on the volatility of earnings of China semiconductor industry but has impact on return of semiconductor industry in China. Despite the fact that China is trying to localize the semiconductor supply chain, import from other countries is inevitable to some extent. The exchange rate fluctuation will still have impact on semiconductor stock price in China. Therefore, in the future, China will have to actively respond to USD to CNY exchange rate variation, seeking to indigenous pace of developing semiconductor industry, to mitigate foreign influence on the industry.

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