RMB Exchange Rate and Stock Return Interactions In Chinese Financial Market: Evidence of CNY, CNH-CNY Spread and Capital Flow Change

by

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Abstract

This research investigates the interactions between RMB exchange rates and stock return in the Chinese financial market. The aim is to establish the causal linkages between the Chinese foreign exchange market and stock market against China's unique backgrounds: 1) China has only one currency but a dual exchange system: CNY[1] traded in Mainland and CNH[2] traded in Hong Kong; 2) the spread between CNH and CNY together with its volatility imply potential arbitrage opportunities for stock investors; 3) China is making ongoing attempts to develop the stock market with policy shift to RMB internalization, Shanghai-Hong Kong stock connect, etc. The research applies the Granger causality test, impulse response and variance decomposition analysis to Vector Autoregressive (VAR) models using daily observations on the Shanghai Stock Exchange Composite Index return and RMB exchange rates, as well as the quarterly national capital flow change over August 23, 2010 to September 22, 2016. The empirical analysis identifies some major conclusions: The CNH-CNY spread has great predictability in stock performance because CNH is a measurement based on market demand while CNY is under control, indicating the market expectation of the future value of RMB. However, the volatility of CNH-CNY spread is inappropriate to be used as a proxy to predict stock performance trend due to its small economic value. From a macroeconomic perspective, China's national capital flow change likely acts as a channel between stock market and exchange market to transmit the influence among the rates.

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To my thesis advisor Professor Robert F. Whitelaw, I really appreciate your great support throughout my whole research process. Thanks for being interested in my research topic and

[1] CNY is the Chinese onshore Renminbi that circulates on mainland China.
[2] CNH is the Chinese offshore Renminbi that circulates outside mainland China (mainly in Hong Kong).

accepting me to be your advisee from the very beginning. Your detailed feedback and insightful guidance helps a lot for my thinking and learning process. I really learned a lot from this research project, not only in terms of the econometrics software techniques, but also the way to think problems comprehensively and find solutions efficiently. Thanks to your expertise and careful advising, I can achieve the whole project successfully from scratch.

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1. Introduction

Study on the interactions between foreign exchange rates and stock price has been popular in developed international capital markets since the early 1980s. In the recent decades, the liberalization of capital control and the reforms on free-floating exchange rates in emerging Asian countries expanded the research scope on the relationship between exchange and stock markets. This research examines the topic in the context of emerging China. Since 2015, China has experienced a drastic decline in RMB exchange rate these days. Reported by Xinhua Finance Agency, on January 6, 2016, RMB sharply declined 400 basis points from around 6.6370 yuan per US dollar to 6.6877 yuan per US dollar, representing a single day loss of more than 0.6%[3]. Similarly, during the period of RMB devaluation from January 10, 2016, Chinese stock market also suffered volatile price fluctuations. According to CNBC, the Shanghai Stock Exchange stock price dropped about 640 basis points from January 1 to January 18[4]. The declining trend in both RMB exchange rate and stock price indicates the potential positive correlation between the two rates.

With China's foreign exchange system reform deepening, the foreign exchange market framework has been formed, which provides more international investment opportunities and allows more volatilities in the exchange market. On July 19th, 2010, the People's Bank of China and the Hong Kong Monetary Authority jointly announced that the RMB would be deliverable in Hong Kong, thus creating the offshore CNH market where foreign individuals and corporations are allowed to buy, hold or sell CNH. CNY is usually treated as an exchange rate under control, whereas CNH reflects more about the market demand. The difference of the two rates, which is the CNH-CNY spread, may indicate potential investment opportunities in the stock market.

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[3] See "Capital flight big story in China: John Rutledge", CNBC, January 2016.
[4] See "CNH rate acted like 'roller coaster'", Xinhua Finance Agency, 2016.

The research on the transmission mechanism between exchange market and stock market has great significance, since the conclusion of the analytics can provide insights for both investors and regulators. If there existing a certain interdependence between RMB exchange rate and stock return, investors who hold shares in the stock market can use RMB exchange rate as an indicator to predict the future stock price trend and make right decisions on their investments. For regulators, the presumable correlation between the RMB exchange rates and stock return and can also suggest that Chinese government should be cautious in their implementation of exchange rate policies, given that such policies may have certain ramifications on their stock markets.

2. Literature Review

A number of foreign literatures raised the hypothesis that strong internal relationship between exchange rate and stock performance exists in the capitalist market. One classical theoretical hypothesis is the flow oriented model applied in good market (Dornbusch and Fischer 1980), which claims that the change in exchange rate influence the competitiveness of multinational firms via input and output prices. Share price of the companies are also impacted by future cash flows of the firms driven exchange rate changes. The model suggests that, when the local currency depreciates, exporting goods becomes cheaper. This leads to higher sales and demand in the foreign market. In contrast, an appreciation of the local currency makes importing goods cheaper, which drives higher sales and demand domestically. From the perspective of profits, a depreciation of local currency causes lower profits for importers whereas provides benefits for exporters with the lower price of the local currency. In consequence, the model concludes that exchange rate changes lead to domestic stock price returns, and they are positively correlated. Conversely, stock price can also influence exchange rate based on the portfolio-balance model (Branson 1977). The model proposes that exchange rate involves in the financial market system as the price of foreign currency. Its movements are correlated with variations in stock prices, corporate value, etc.

Although theoretical models imply strong linkages between exchange rates and stock prices, empirical findings vary by using different testing methodologies. Muriithi (2011)'s study on the relationship between exchange rates and stock performance of manufacturing companies shows that the two rates are positively correlated. However, Kim gets different result by investigating the existence of long-run equilibrium relationship among the aggregate stock price and real exchange rate in the US. By applying Johansen's co-integration analysis to monthly data for the period from January 1974 to December 1998, Kim finds that the S&P 500 stock price is negatively related to the real exchange rate. The conclusion about the negative correlation between the two parameters is not applicable to Chinese stock market[5]; otherwise the stock price should have increased during the recent RMB devaluation.

Different from the US who runs free stock market and implements the policy of floating exchange rate without capital control, China limits the RMB exchange rate within a certain range and the stock market involves a lot of government intervention. In order to look deeper into the dynamic linkages between exchange rate and stock market in Chinese context, Chinese researcher Tang (2007) explained that exchange rate influences stock price via the increase of domestic currency release. Huang (2001) claims the role of interest rate as the intermediate channel that connects the exchange rate and stock market. Based on these evidence, Zhang et al expended to test the interactions between CNY and Shanghai Composite index of both A share and B share by using CNY rates collected from 2005 to 2008 right after the exchange rate reform. The test shows the short-term causality relationship between CNY and the prices of both A and B share. Stock performance leads to exchange

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[5] See Exhibit 1 in the Appendix. Exhibit 1 shows that, in general, when CNY depreciates, SSE Composite Index goes down.

rate movement in a larger extent. Since the increase of stock price foreign capital investment, investors sell foreign currency to buy CNY, with which they invest in stocks in Chinese financial market. The fast circulation of capital flow increases the demand of CNY, which drives CNY to appreciate, attracting much more hot money into China. Yi (2006) also conducts analysis on the influence of CNY on the extent of capital flight, drawing the conclusion that the depreciation of CNY after 2002 fuels large amount of foreign currencies entering China market.

With the establishment of CNH market in 2010, more scholars pay attention to the relationship[6] between CNY and CNH. Before that, researchers usually use non-deliverable forward (NDF)[7] as a proxy to measure or predict the expectations of future RMB movement (Li 2008 and Jiang 2012). For instance, Sha (2014) uses structural vector autoregressive (SVAR) model on NDF and CNY to predict the expected value of RMB. Much current research tries to analyze the arbitrage investment opportunities in the CNH market by looking at the appreciation and depreciation trend[8] of CNY and CNH, but few statistical research has looked deeper into the implication of the CNH-CNY spread, the volatility of the CNH-CNY spread, as well as how the capital flow moves when CNY and CNH changes relatively. Tong et al (2016)'s recent work shows that there exists some out-of-sample predictive power of NDF on CNY before 2013. But with the establishment of CNH market, RMB movement right now is less related to NDF pricing. Therefore, taking a serious look on the interactions among CNH-CNY spread (and its volatility), the capital flow movement and the stock market performance is vital for making investments in China's the exchange and stock markets.

[6] See Exhibit 2 and 3 in the Appendix for an overview of the relationship between CNY and CNH.

[7] A NDF is an outright forward or futures contract in which counterparties settle the difference between the contracted NDF price or rate and the prevailing spot price or rate on an agreed notional amount. The calculation formula for expected RMB value: Expected= $\frac{CNH(ndf)-CNY(spot)}{CNY(spot)}$.

[8] See Exhibit 4 in the Appendix for an overview of the appreciation and depreciation trend.

3. Hypotheses

China's unique dual exchange system and capital control from government make the situation of China quite different from western countries. It is interesting to examine whether Dornbusch and Branson's classical economic models are applicable to Chinese financial market. Moreover, how statistics can prove the models with economic significance. Based on this aim, the paper test the following two hypotheses.

Hypothesis I: There are bidirectional causality relationships between RMB exchange rates and stock return. However, the significance of causality varies both when choosing different statistical measurements for RMB exchange rates and stock return, and incorporating different number of variables into models.

Hypothesis II: The volatility of CNH-CNY spread has certain predictability on future exchange rate movements, which may suggest investment opportunity from a macroeconomic perspective.

Potentially, the interactions of CNH-CNY spread and stock prices is realized through the channel of capital flow movements as flow oriented and portfolio balance suggest. When CNH-CNY spread rises, investors expect high CNY value in the future, and put more capital to the stock market in mainland China, which lifts the stock price. As for the second hypothesis, a potential explanation is that, different from countries implementing independently floating exchange rates where high exchange rate volatility may indicate bad macroeconomic environments, high RMB exchange rates in China may suggest the promising macroeconomic environment expected by Chinese government, so that it does not intervene by restricting RMB exchange rate policy.

4. Data Description

The research chooses nominal CNH, CNY exchange rates associated with USD as measurements of RMB exchange rates, and Shanghai Stock Exchange (SSE) Composite Index[9] as measurement of stock return over the time period from August 23, 2010 till September 22, 2016 from *Bloomberg* database. The reason for the time period selection is that the CNH rates are recorded only after August 23, 2010, for the CNH market was just established on July 19, 2010 when the People's Bank of China and the Hong Kong Monetary Authority signed a new Currency Liquidation Agreement. Choosing SSE Composite Index to measure stock return is because it is one of the most representative index in China's stock market. The total observations of date remain 1561 after removing the dates when not all of the three measurements exist. Another data set selected is the quarterly capital flows of China from September 30, 2010 to June 30, 2016. This set of data is collected from the *Trading Economics* platform. Because the data of capital flows[10] on a national level is only published in quarterly basis, we only can get 24 observations from September 2010 to June 2016.

5. Methodology

The research uses econometrics software Eviews 9.0 to conduct data analytics. To verify the hypotheses mentioned previously, the paper adopts the following methodology. First, conducting the correlation analysis between exchange rates and stock returns. Second, applying Augmented Dickey-Fuller (ADF) unit root test to check whether the data sequences are stationary or not. Then, using Granger causality test based on vector autoregressive (VAR) models to examine whether there exists bidirectional causality relationship among the measurements. Finally, using methods of impulse response analysis and variance decomposition to analyze the effect of one innovation change on the whole VAR system.

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[9] Shanghai Stock Exchange (SSE) Composite Index is a stock market index of all stocks (A shares and B shares) that are traded at the Shanghai Stock Exchange.

[10] See Exhibit 5 in the Appendix for an overview of the 24 capital flow observations.

First, the research builds up the VAR model based on which the methodologies can be applied. In order to look into dynamic interactions between the exchange rates and stock performance, the research starts with building VAR models with three variables: percent change of CNY (denoted as %ΔCNY[11]), percentage amount of CNH-CNY spread in CNY (denoted as %CNH-CNY Spread[12]) and stock return (denoted as SR[13]). The VAR system is as below.

$$\%\Delta CNY_t = \sum_{i=1}^{t} a_i \, \%\Delta CNY_{t-i} + \sum_{i=1}^{t} b_i \, \%(CNH - CNY)_{t-i} + \sum_{i=1}^{t} d_i \, SR_{t-i} + C_1 + \varepsilon_t$$

$$\%(CNH - CNY)_t = \sum_{i=1}^{t} e_i \, \%\Delta CNY_{t-i} + \sum_{i=1}^{t} f_i \, \%(CNH - CNY)_{t-i} + \sum_{i=1}^{t} g_i \, SR_{t-i} + C_2 + \varepsilon_t$$

$$\%SR_t = \sum_{i=1}^{t} h_i \, \%\Delta CNY_{t-i} + \sum_{i=1}^{t} j_i \, \%(CNH - CNY)_{t-i} + \sum_{i=1}^{t} k_i \, SR_{t-i} + C_3 + \varepsilon_t$$

where $a_i, b_i, d_i, e_i, f_i, g_i, h_i, k_i$ are correlation coefficients, C_1, C_2, C_3 are constants, i denotes the number of lags involved in the system, and ε_t summarizes the error term beyond the independent variables at time period t.

To further examine the potential causal impact of RMB exchange rate volatility, the research adds the volatility of CNH-CNY spread (denoted as Var (CNH-CNY Spread)) to the system to form the VAR model with four variables. The volatility of CNH-CNY spread is calculated by GARCH (1,1)[14] model. The additional equation incorporated into the system is written as below.

$$Var(CNH - CNY\ Spread)_t = \sum_{i=1}^{t} l_i \, Var(CNH - CNY\ Spread)_{t-i} +$$
$$\sum_{i=1}^{t} a_i \, \%\Delta CNY_{t-i} + \sum_{i=1}^{t} b_i \, \%(CNH - CNY)_{t-i} + \sum_{i=1}^{t} d_i \, SR_{t-i} + C_4 + \varepsilon_t$$

where the new l_i is correlation coefficient, C_4 is constant.

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11 $\%\Delta CNY^{11} = \frac{CNY_{t+1} - CNY_t}{CNY_t}$

12 %CNH-CNY Spread= $\frac{(CNH-CNY)_t}{CNY_t}$

13 SR=$\frac{SHC_{t+1} - SHC_t}{SHC_t}$

14 GARCH (1,1) here is the standard Generalized Autoregressive Conditional Heteroskedasticity Process model by adopting 1st order of GARCH terms σ^2 and 1st order of ARCH terms ϵ^2.

Finally, in order to investigate the implication of national capital flow movement in the linkages, the research builds another VAR model with five variables by adding the variable of quarterly capital flow (denoted as CF). To eliminate the potential bias of correlation coefficient due to large difference between the nominal value of capital flow and exchange rates, the capital flow measurement is normalized here. The additional equation in the system is as below.

$$CF_t = \sum_{i=1}^{t} m_i\, CF_{t-i} + \sum_{i=1}^{t} l_i\, Var(CNH - CNY\ Spread)_{t-i} + \sum_{i=1}^{t} a_i\, \%\Delta CNY_{t-i} + \sum_{i=1}^{t} b_i\, \%(CNH - CNY)_{t-i} + \sum_{i=1}^{t} d_i\, SR_{t-i} + C_5 + \varepsilon_t$$

where the new m_i is the correlation coefficient, C_5 is constant.

6. Empirical Results

6.1. Test on VAR with 3 Variables

6.1.1. Statistical Description

According to Table 1, the value of $\%\Delta CNY$, $\%(CNH - CNY\ Spread)_t, SR$ are small with the mean and median floating around 0.0001. The floating range of stock return is slightly larger than the exchange rate measurements. The correspondent Kurtosis of the three variables are 30.85179, 11.91886, and 8.491827, indicating that the observations do not follow normal distribution. In terms of skewness, the distribution of $\%\Delta CNY$ displays the feature of thick tail on the right, whereas $\%(CNH - CNY\ Spread)_t\ and\ SR$ skewed to the left.

	$\%\Delta \boldsymbol{CNY_t}$	$\%(\boldsymbol{CNH - CNY\ Spread})_t$	$\boldsymbol{SR}$
Mean	-1.14E-05	0.000182	0.000195
Median	-1.56E-05	4.82E-05	0.000000
Maximum	0.018568	0.021431	0.057635
Minimum	-0.011880	-0.025600	-0.084909
Std. Dev	0.001382	0.004068	0.014632
Skewness	1.374546	-0.072316	-0.839644
Kurtosis	30.85179	11.91886	8.491827

Observations	1561	1561	1561

Table 1. Statistical Description of the variables

6.1.2. ADF Test Result Analysis

From Table 2, the t-statistic of ADF test is smaller than the critical values on all the levels of 1%, 5% and 10%. Then, we can reject all the null hypothesis that the variables have unit root. Therefore, all the three sequences can be regarded as stationary.

Null Hypothesis: $\%\Delta CNY$ has a unit root		**t-Statistic**	**Prob.***
Augmented Dickey-Fuller Test Statistic		-37.65758	0.0000
Test critical values	1% level	-3.434336	
	5% level	-2.863187	
	10% level	-2.567695	

Null Hypothesis: $\%(CNH - CNY\ Spread)$ has a unit root		**t-Statistic**	**Prob.***
Augmented Dickey-Fuller Test Statistic		-6.719871	0.0000
Test critical values	1% level	-3.434336	
	5% level	-2.863187	
	10% level	-2.567695	

Null Hypothesis: SR has a unit root		**t-Statistic**	**Prob.***
Augmented Dickey-Fuller Test Statistic		-37.77175	0.0000
Test critical values	1% level	-3.434336	
	5% level	-2.863187	
	10% level	-2.567695	

Table 2. ADF Test for percent change of CNY, percentage amount of CNH-CNY Spread in CNY and daily stock return

6.1.3. Granger Causality Test Result Analysis

6.1.3.1 VAR Lag Selection

Since the data is in high frequency, the effect may not be real-time enough if we select too many lags when running causality test. So the research limits the maximum of lags to 4 and do lag pre-estimation on the 3-varibale VAR to see which lag suits the model well. From the indicators with "*" in Table 3, we get that the criteria of LR, FPE, AIC suggest choosing lag 4, another two criteria of SC and HQ suggest choosing lag 2. Since the data is high-frequency, the impact of which is stronger in short term. Then the research follows the SC and HQ criteria, choosing lag 2 to build VAR (2) to measure the instant impact of the variables more accurately.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	18795.99	NA	6.59e-15	-24.14000	-24.12969	-24.13617
1	20395.51	3190.813	6.54e-16	-26.18305	-26.14182	-26.16772
2	20430.48	69.62640	8.26e-16	-26.21641	-26.14425*	-26.18958*
3	20441.64	22.19230	8.24e-16	-26.21920	-26.11610	-26.18086
4	20450.93	18.40863*	8.23e-16*	-26.21956*	-26.08554	-26.16972

*indicate lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Table 3. Lag pre-estimation

6.1.3.2. VAR (2) Model Estimation

From the VAR (2) model estimation in Eviews 9.0, the research obtains equations.

$$\%\Delta CNY_t = 0.056541 * \%\Delta CNY_{t-1} - 0.053468 * \%\Delta CNY_{t-2} + 0.171301 * \%(CNH - CNY)_{t-1} - 0.137768 * \%(CNH - CNY)_{t-2} + 0.005404 * SR_{t-1} + 0.005398 SR_{t-2} - 2.06E - 05 + \varepsilon_t$$

$$\%(CNH - CNY)_t = 0.037990 * \%\Delta CNY_{t-1} + 0.042521 * \%\Delta CNY_{t-2} + 0.824856 * \%(CNH - CNY)_{t-1} + 0.110641 * \%(CNH - CNY)_{t-2} - 0.001305 * SR_{t-1} + 0.001004 * SR_{t-2} + 2.09E - 05 + \varepsilon_t$$

$$SR_t = -0.179471 * \%\Delta CNY_{t-1} + 0.088119 * \%\Delta CNY_{t-2} - 0.911405 * \%(CNH - CNY)_{t-1} - 0.6262 * \%(CNH - CNY)_{t-2} + 0.036706 * SR_{t-1} - 0.039100 * SR_{t-2} + 0.000263 + \varepsilon_t$$

From the three equations in VAR (2) above, the adjusted coefficient of determination is 0.041921 for $\%\Delta CNY_t$, 0.871905 for $\%(CNH - CNY)_t$, and 0.011521 for SR_t. The goodness to fit of the $\%(CNH - CNY)_t$ equation is large. It is reasonable that the adjusted coefficients of determination on $\%\Delta CNY_t$ and SR_t is small, since there are other factors, such as government control, investor's expectation, influencing the movement of CNY and stock return in the market. However, by looking at the coefficients, we can still have a deeper understanding about the correlations among the variables.

In the first equation, the coefficients of both 1 and 2 lagged stock return are all positive, implying that an increase in stock return is related to a percentage increase in CNY rate. However, for the coefficients of $\%\Delta CNY$ and $\%(CNH - CNY)$, a reversal phenomenon occurs: the coefficient of 1 lagged variable is positive, whereas that of 2 lagged variable is negative. However, the sum of the coefficients with $\%\Delta CNY$ and $\%(CNH - CNY)$ are positive, meaning the shorter-term positive impact of $\%\Delta CNY$ and $\%(CNH - CNY)$ offsets the longer-term negative impact, leading to a positive impact overall.

In the second equation, the coefficients of $\%\Delta CNY$ and $\%(CNH - CNY)$ are both positive, meaning that percentage change of CNY and percentage amount of CNH-CNY spread in CNY may promote a larger percentage of CNH-CNY in CNY. We can explain in the economic context. When CNY is stronger than CNH currently, the market expects the CNH to appreciate and CNH goes stronger in the next period. In terms of the magnitude of coefficients, $\%(CNH - CNY)$ is largely related to its own historical performance. A reversal phenomenon occurs to stock return variable: the 1 lagged stock return is negatively related to $\%(CNH - CNY)$, while the impact of 2 lagged stock return is positive.

In the third equation, the two coefficients of $\%(CNH - CNY)$ are all negative. Reversal phenomenon occurs to $\%\Delta CNY$ and stock return. The coefficient of 1 lagged $\%\Delta CNY$ is negative, whereas that of 2 lagged $\%\Delta CNY$ is positive. The coefficient of 1 lagged stock return is positive, whereas that of 2 lagged stock return is negative. However, if we sum the coefficients magnitudes, the overall impact is negative.

6.1.3.3. Granger Causality Test

From Table 4, we can see that there is no Granger causality between $\%\Delta CNY$ and %(CNH-CNY Spread), $\%\Delta CNY$ and stock return, stock return and %(CNH-CNY Spread). However, unidirectional causality relationship exists between %(CNH-CNY Spread) and $\%\Delta CNY$, stock return and $\%\Delta CNY$, %(CNH-CNY Spread) and stock return. The change of %(CNH-CNY Spread) gives signal to market about the expected value of CNY in the future. Stock return suggests the good economic environment of China in terms of investment in stock market, which make the value of CNY to increase. %(CNH-CNY Spread) measures the difference of RMB exchange rates traded domestically and globally. The gap between CNH and CNY indicates certain buy and sell opportunities related to cross-border trading, which causes the changes in the stock market.

Null Hypothesis	Obs	F-Statistic	Probability	Result
$\%\Delta \boldsymbol{CNY}$ does not Granger Cause $\%(\boldsymbol{CNH-CNY\ Spread})$	1559	2.41355	0.0898	Accept H_0
$\%(\boldsymbol{CNH-CNY\ Spread})$ does not Granger Cause $\%\Delta \boldsymbol{CNY}$	1559	28.0347	1.E-12	Reject H_0
Stock return does not Granger Cause $\%\Delta \boldsymbol{CNY}$	1559	3.82075	0.0221	Reject H_0
$\%\Delta \boldsymbol{CNY}$ does not Granger Cause stock return	1559	0.23247	0.7926	Accept H_0
Stock return does not Granger Cause $\%(\boldsymbol{CNH-CNY\ Spread})$	1559	0.26672	0.7659	Accept H_0
$\%(\boldsymbol{CNH-CNY\ Spread})$ does not Granger Cause stock return	1559	9.37998	9.E-05	Reject H_0

Table 4. Granger Causality Test among Variables

6.1.4. Impulse Response Function Analysis

Impulse Response Function (IRF) describes the effect of a shock on one endogenous variable on other endogenous variables in VAR model. Figure 1 to 3 show the graph of IRF, where the horizontal axis stands for the number of lags, whereas the vertical axis stands for the extent of influence affected by the innovation.

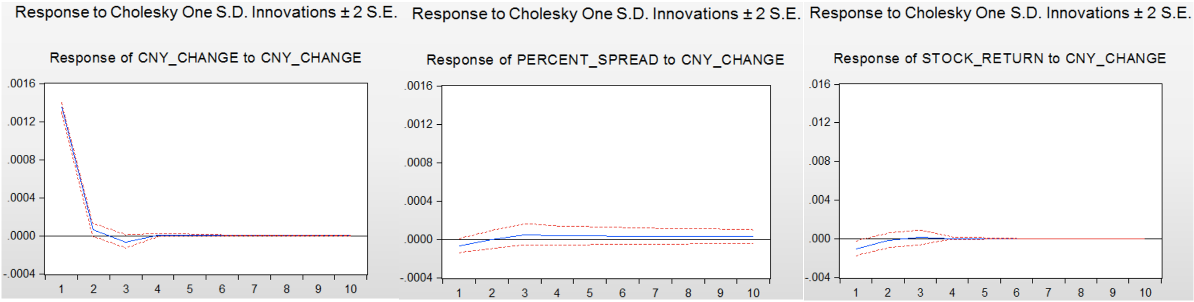


Fig 1. Response of variables (percent change of CNY, percentage amount of CNH-CNY Spread in CNY and daily stock return) to One S.D. Innovation of percent change of CNY

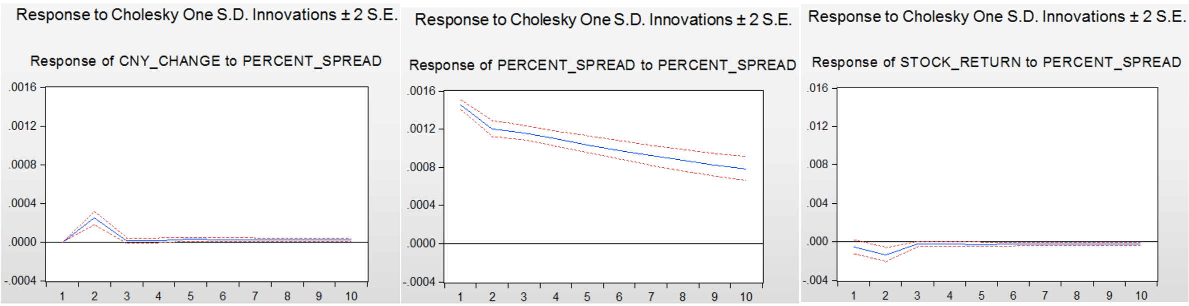


Fig 2. Response of variables (percent change of CNY, percentage amount of CNH-CNY Spread in CNY and daily stock return) to One S.D. Innovation of percentage amount of CNH-CNY Spread in CNY

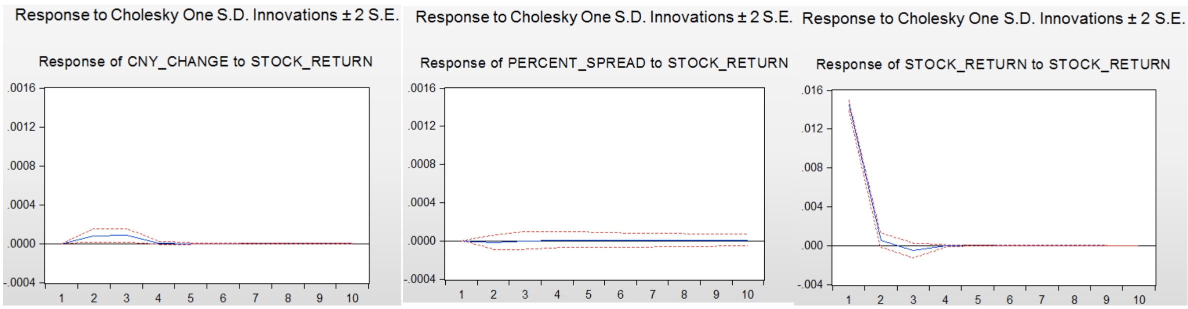


Fig 3. Response of variables (percent change of CNY, percentage amount of CNH-CNY Spread in CNY and daily stock return) to One S.D. Innovation of stock return

From Figure 1, one standard innovation on $\%\Delta CNY$ will make $\%\Delta CNY$ itself increase in the following 2 days. After reaching the mountain by the following 2 days and a half, the shock exerts negative impact until the innovation disappear on the following 4th day. However, the innovation on $\%\Delta CNY$ have little impact on %(CNH-CNY Spread) and stock return. From Figure 2, one standard innovation on %(CNH-CNY Spread) will increase the $\%\Delta CNY$ in the following 3 days and the impact of innovation diminishes to 0 then. Within the following 10 days, the innovation will continue increasing %(CNH-CNY Spread) itself. However, the impact on stock return is generally negative but very little. As Figure 3 displays, the innovation on stock return mainly have positive impact on itself rather than the others.

6.1.5. Variance Decomposition Analysis

Variance decomposition is to evaluate the importance of different shocks by analyzing the contribution of each shock to the changes of different endogenous variables in VAR model. In our VAR (2), the graph of variance decomposition is as below.

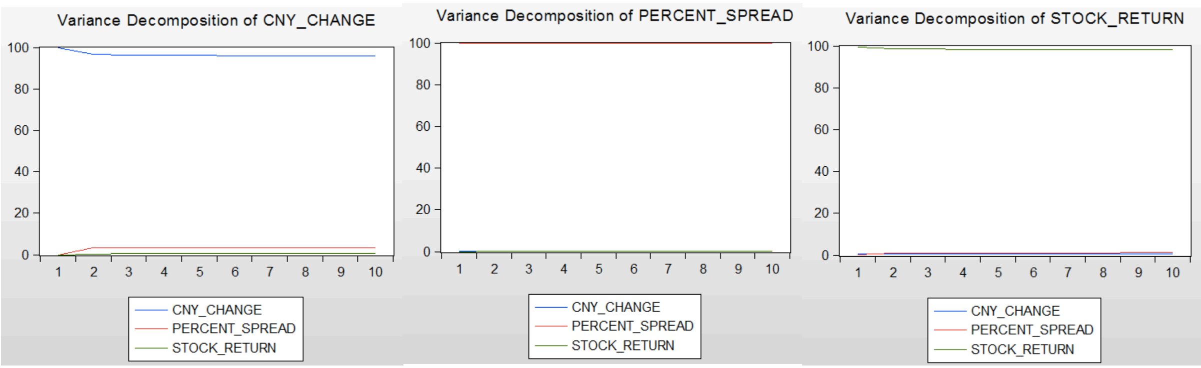


Fig 4. Variance decomposition of variables (percent change of CNY, percentage amount of CNH-CNY Spread in CNY and daily stock return

From Figure 4, the variance of each variable is almost explained by its own historical performance. In comparison, the variance $\%\Delta CNY$ is also explained by %(CNH-CNY Spread) around 0 to 5%. Although the influence of %(CNH-CNY Spread) increases within the first 2 days, but it is really limited and stays around 5% afterwards. In the cases of %(CNH-CNY Spread) and stock return, the dominance influence of the variable itself is even much stronger.

6.2 Test on VAR Model with 4 Variables

6.2.1. Statistical Description

Based on the VAR with 3 variables, the new 4-variabe model just add the measurement of volatility of %(CNH-CNY Spread), denoted as Var (Spread). To obtain the sequence of Var (Spread), the research adopts the GARCH (1,1) model[15]. The range of Var (Spread) is even smaller compared to others, since due to the exchange rate policy control on CNY, the government generally monitors the rate of CNY based on the market environment. The Kurtosis of 23.41907 suggest the sequence does not distribute normally. According to the skewness, the distribution of Var (Spread) is skewed to right.

	$\%\Delta CNY_t$	$\%(CNH - CNY\ Spread)_t$	***SR***	***Var(Spread)***
Mean	-1.14E-05	0.000182	0.000195	2.18E-06
Median	-1.56E-05	4.82E-05	0.000000	1.22E-06
Maximum	0.018568	0.021431	0.057635	2.54E-05
Minimum	-0.011880	-0.025600	-0.084909	4.00E-07
Std. Dev	0.001382	0.004068	0.014632	2.72E-06
Skewness	1.374546	-0.072316	-0.839644	4.022032
Kurtosis	30.85179	11.91886	8.491827	23.41907
Observations	1561	1561	1561	1561

Table 5. Statistical Description of the 4 variables

6.2.2. ADF Test Result Analysis

From Table 6, the t-statistic of ADF test is smaller than the critical values on the levels of 1%, 5% and 10%. Then, we can reject all the null hypothesis that the variables have unit root. Therefore, the sequence of Var (Spread) is stationary.

Null Hypothesis: $Var(Spread)$ has a unit root		**t-Statistic**	**Prob.***
Augmented Dickey-Fuller Test Statistic		-7.609717	0.0000
Test critical values	1% level	-3.434338	
	5% level	-2.863189	
	10% level	-2.567696	

Table 6. ADF Test for Volatility of Var (Spread)

6.2.3. Granger Causality Test Result Analysis

[15] See Exhibit 6 and 7 in the Appendix for the GARCH (1,1) test.

6.2.3.1. VAR Lag Selection

Follow the previous process, the research limits the maximum of lags to 4 and do lag pre-estimation on the 4-varibale. From the indicators with "*" in Table 7, we get that the criteria of LR, FPE, AIC suggest choosing lag 8, the criteria of SC suggests choosing lag 1 and HQ suggest choosing lag 2. Since the data is high-frequency, the impact of which is stronger in short term. Since SC is the one rule used more frequently in the industry, the research follows the SC criteria, choosing lag 1 to build VAR (1) to measure the instant impact of the variables more accurately.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	36514.39	NA	4.47e-26	-47.01918	-47.00540	-47.01405
1	39681.89	6314.602	7.71e-28	-51.07777	-51.00890*	-51.05216
2	39734.18	103.9675	7.36e-28	-51.12450	-51.00053	-51.07840*
3	29749.19	29.77367	7.37e-28	-51.12323	-50.94416	-51.05664
4	39773.83	48.75010	7.29e-28	-51.13436	-50.90020	-51.04728
5	39790.37	32.62124	7.29e-28	-51.13505	-50.84579	-51.02748
6	39803.88	26.58366	7.31e-28	-51.13184	-50.78748	-51.00378
7	39823.47	38.44472	7.27e-28	-51.13647	-50.73701	-50.98791
8	39849.93	51.80984*	7.18e-28*	-51.14995*	-50.69539	-50.98090

*indicate lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Table 7. Lag pre-estimation

6.2.3.2. VAR Model Estimation

From the VAR (1) model estimation, the research obtains the following equations.

$\%\Delta CNY_t = 0.0428 * \%\Delta CNY_{t-1}$ -12.73519$*$ $Var(Spread)_{t-1}$ +0.041719*$\%(CNH - CNY\ Spread)_{t-1}$ - 0.005657$*$ $SR_{t-1} + 8.19E-06 + \varepsilon_t$

$Var(Spread)_t$=7.22E-05*$\%\Delta CNY_{t-1}$+0.924977$*$ $Var(Spread)_{t-1}$ + 2.18E-05*$\%(CNH - CNY\ Spread)_{t-1}$-4.2E-06$*$ SR_{t-1}+$1.61E-07$+ε_t

$\%(CNH - CNY\ Spread)_{t-1} = 0.0052124 * \%\Delta CNY_{t-1} + 0.730941 * Var(Spread)_{t-1} +$

$0.928862 *\%(CNH - CNY\ Spread)_{t-1} - 0.001286 * SR_{t-1} + 1.96E - 05 + \varepsilon_t$

$SR_t = -0.131346 * \%\Delta CNY_{t-1} - 35.75743 * Var(Spread)_{t-1} - 0.294926 * \%(CNH - CNY\ Spread)_{t-1} + 0.035154 * SR_{t-1} + 0.000315 + \varepsilon_t$

From the three equations in VAR (1) above, the adjusted coefficient of determination is 0.018332 for $\%\Delta CNY_t$, 0.879971 for Var (Spread), 0.870640 for $\%(CNH - CNY)_t$, and 0.009281 for SR_t. The goodness to fit of the Var (Spread) and $\%(CNH - CNY)_t$ equation is large. Similar as the VAR with 3 variables, the adjusted coefficients of determination on $\%\Delta CNY_t$ and SR_t is small due to the influence of other factors beyond the four variables. The reversal coefficients do not appear since we choose 1 lag. By looking at the magnitude of the coefficients, we can see that the coefficients before Var (Spread) are large in all four equations, where the impact of Var (Spread) is negative to $\%\Delta CNY_t$ and stock return, but positive to Var (Spread) itself and $\%(CNH - CNY)_t$. That is, when the volatility of CNH-CNY increases, the percentage increase of CNY decreases (i.e. CNY depreciates), and stock performance is worse. And the more volatile the CNH-CNY spread is, the market probably expect more volatile market and the spread becomes more stable. In terms of the $\%(CNH - CNY\ Spread)$, since CNY depreciates, the spread is wider, when it is divided by a lower CNY, the value as a whole increases.

6.2.3.3. Granger Causality Test

From Table 8, we can observe that by adding the additional variable, the number of pairs that appear with Granger Causality increases. Different from VAR with 3 variables, $\%\Delta CNY$ and $\%(CNH - CNY\ Spread)$ now has a bidirectional causality relationship. There are also new pairs involving Var (Spread) that present the causality: Stock return Granger Causes Var (Spread), %ΔCNY Granger Causes Var (Spread), (CNH-CNY Spread) Granger Causes Var (Spread). In this case, it is surprising to find that, actually Var (Spread) does not cause other variables directly. But the volatility of CNH-CNY spread can somehow be implied by other variables.

Null Hypothesis	Obs	F-Statistic	Probability	Result
$\%\Delta \boldsymbol{CNY}$ does not Granger Cause $\%(\boldsymbol{CNH - CNY\ Spread})$	1560	3.93094	0.0476	Reject H_0
$\%(\boldsymbol{CNH - CNY\ Spread})$ does not Granger Cause $\%\Delta \boldsymbol{CNY}$	1560	18.9958	1.E-05	Reject H_0
Stock return does not Granger Cause $\%\Delta \boldsymbol{CNY}$	1560	3.87060	0.0493	Reject H_0
$\%\Delta \boldsymbol{CNY}$ does not Granger Cause stock return	1560	0.54131	0.4620	Accept H_0
Stock return does not Granger Cause $\%(\boldsymbol{CNH - CNY\ Spread})$	1560	0.44461	0.5050	Accept H_0
$\%(\boldsymbol{CNH - CNY\ Spread})$ does not Granger Cause stock return	1560	11.2379	0.0008	Reject H_0
Stock return does not Granger Cause Var(Spread)	1560	10.4273	0.0013	Reject H_0
Var(Spread) does not Granger Cause stock return	1560	1.55059	0.2132	Accept H_0
Var(Spread) does not Granger Cause $\%\Delta \boldsymbol{CNY}$	1560	0.17228	0.6782	Accept H_0
$\%\Delta \boldsymbol{CNY}$ does not Granger Cause Var(Spread)	1560	21.7336	3.E-06	Reject H_0
Var(Spread) does not Granger Cause $\%(\boldsymbol{CNH - CNY\ Spread})$	1560	0.00175	0.9666	Accept H_0
$(\boldsymbol{CNH - CNY\ Spread})$ does not Granger Cause Var(Spread)	1560	16.6109	5.E-05	Reject H_0

Table 8. Granger Causality Test Among the 4 Variables

6.2.4. Impulse Response Function Analysis

The Figure 5 below analyzes how each variable in this VAR reacts to one S.D. innovation on each dependent variables. The response of $\%\Delta CNY$, $\%(CNH - CNY\ Spread)$, and stock return actually displays similarly as the IRF in the VAR without volatility of CNH-CNY spread since the impact of the volatility is small in deed. Within the following 2 to 3 days, it has small positive impact on $\%\Delta CNY$, small negative impact on $\%(CNH - CNY\ Spread)$, but almost no impact on stock return. However, an innovation on Var(Spread) have large continuous positive impact on itself in the following 10 days. An innovation on $\%\Delta CNY$ and $\%(CNH - CNY\ Spread)$ also increases the volatility of spread. Differently, an innovation of stock return decreases the volatility of spread. One potential explanation is that one big factor to influence stock market is the macro-control from the government. When the government intervenes to influence the stock performance, it is probably because the government wants to stabilize the market, so that is likely to have more restrictions on exchange rate, which reduces CNH-CNY spread as a result.

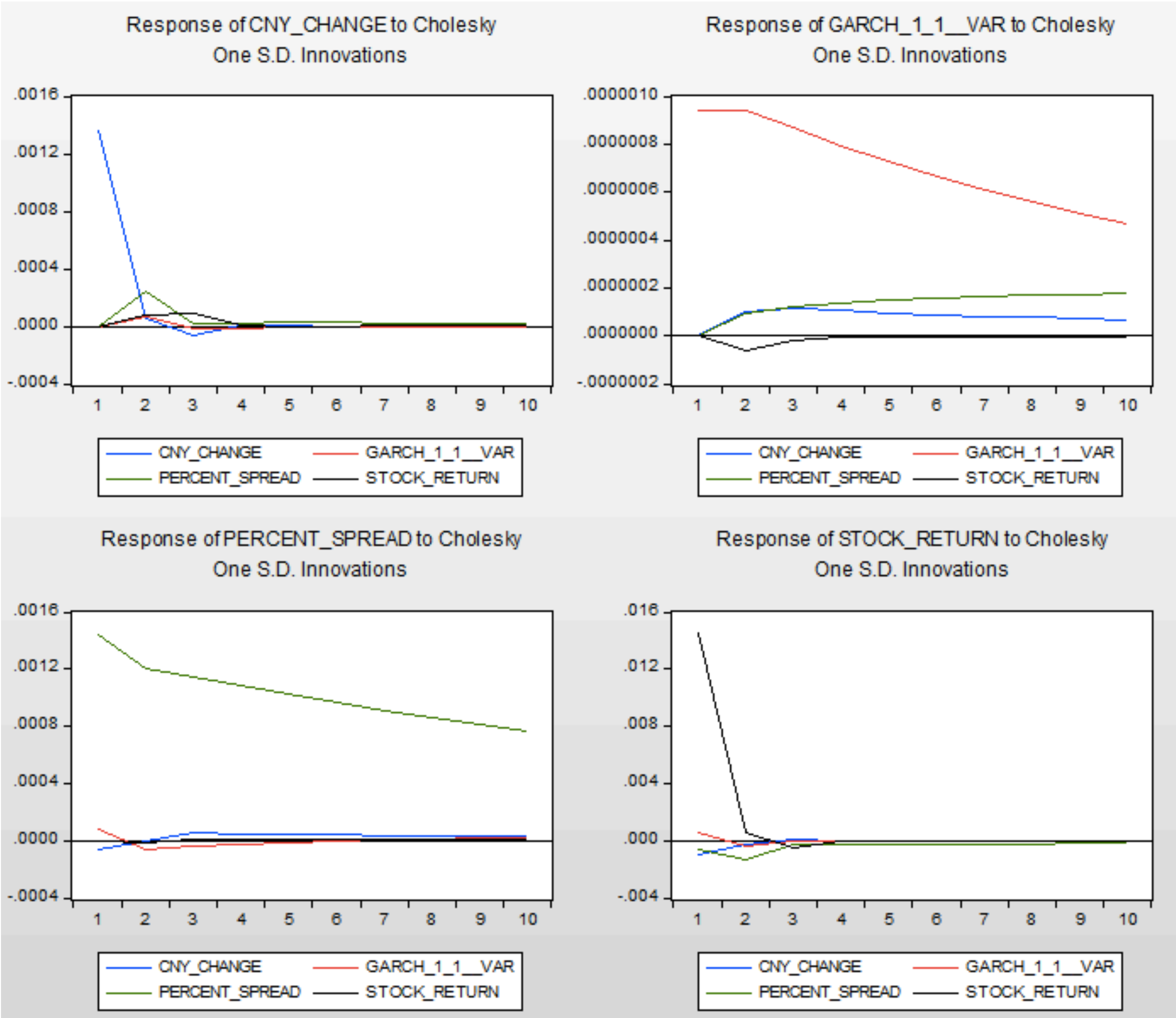


Fig 5. IRF of the variables

6.2.5. Variance Decomposition Analysis

The Figure 6 shows the variance decomposition result of $\%\Delta CNY$, $\%(CNH - CNY\ Spread)$ and stock return is also similar to the VAR with 3 variables due to the small impact of Var (Spread). The variance of CNH-CNY spread volatility is also largely explained by its historical performance. However, the impact of Var (Spread) itself diminishes as the time goes on, whereas the contribution of the of %ΔCNY, %(CNH-CNY Spread) and stock return increases from 0 to 5% within the following 10 days.

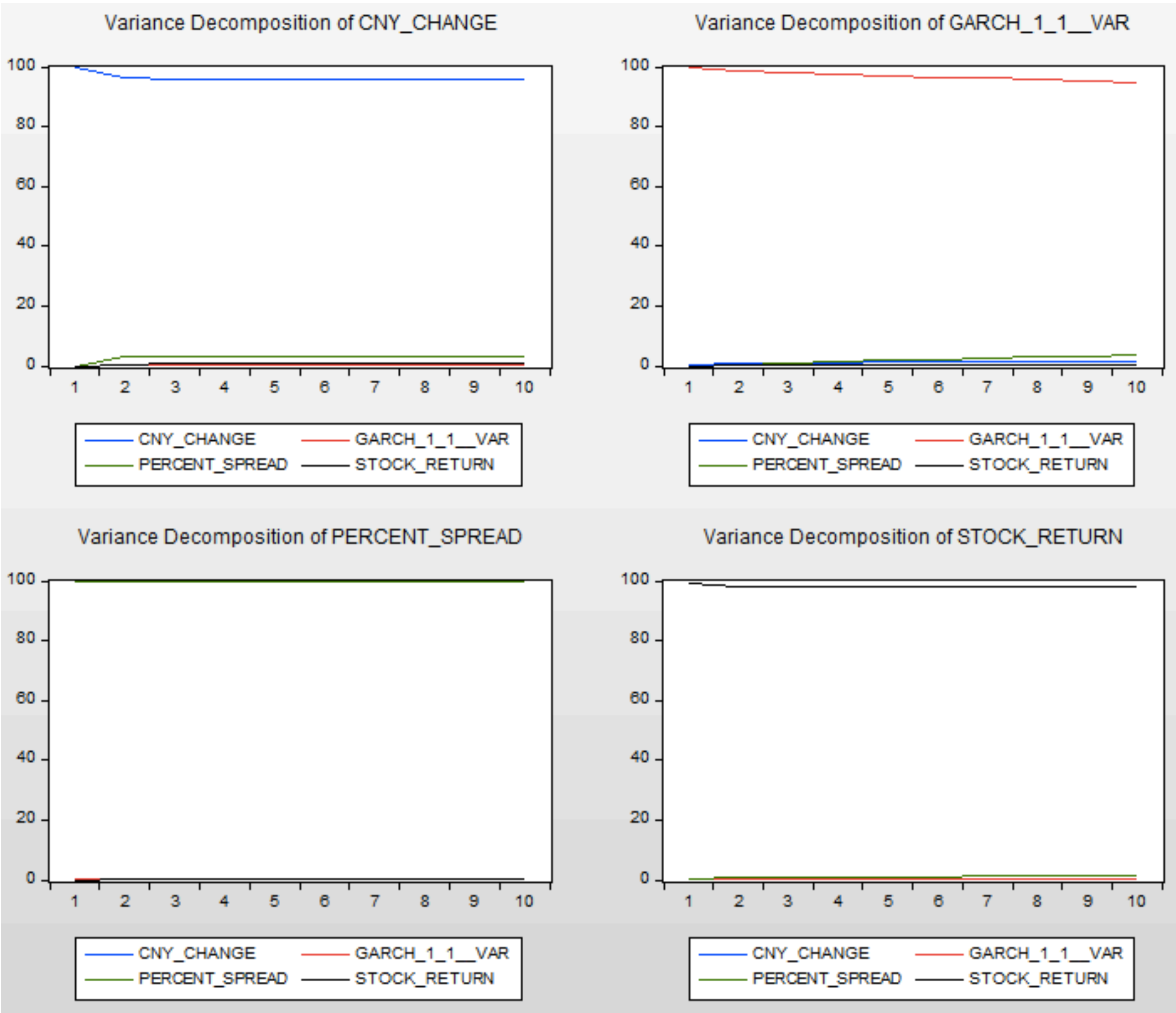


Fig. 6 variance decomposition of the variables

6.3. Test on VAR Model with 5 Variables

6.3.1. Statistical Description

Since the capital flow is low-frequency quarterly data, we collected all the capital flow from September 30, 2010 to June 30, 2016, which matches the time period of other variables but in quarterly basis. The total observation is 24. To get the volatility of CNH-CNY spread quarterly, the research uses the variance formula and calculated the variance for each quarter.

From Table 9, the Kurtosis of $\%(CNH - CNY\ Spread)_t$ is 5.871250. For stock return and Var (Spread), the Kurtosis is 7.12339 and 7.395429, which proves that they are not normal distributed. Apart from the quarterly $\%\Delta CNY$ is skewed to left, the other 4 variables are skewed to the right.

	$\%\Delta \boldsymbol{CNY_t}$	$\%(\boldsymbol{CNH} - \boldsymbol{CNY\ Spread})_t$	***SR***	***Var (Spread)***	***Normalized Capital***
Mean	-0.000930	0.001808	0.008062	9.02E-06	3.42E-16
Median	-0.001208	0.000948	0.006290	2.63E-06	0.151910
Maximum	0.001688	0.017834	0.055314	5.67E-05	2.059549
Minimum	-0.003798	-0.010326	-0.010212	4.74E-07	-1.952759
Std. Dev	0.001356	0.005270	0.013612	1.35E-05	1.000000
Skewness	-0.107638	0.994983	1.577801	2.112744	0.193685
Kurtosis	2.338472	5.871250	7.123390	7.395429	2.437668
Observations	24	24	24	24	24

Table 9. Statistical description of the 5 variables

6.3.2. ADF Test Result Analysis

From Table 10, the t-statistic of ADF test is smaller than the critical values on the levels of 1%, 5% and 10%. Then, we can reject all the null hypothesis that the variables have unit root. Therefore, the sequence of quarterly exchange rates and stock return, as well as normalized capital flow are stationary.

Null Hypothesis: Quarterly %ΔCNY has a unit root		**t-Statistic**	**Prob.***
Augmented Dickey-Fuller Test Statistic		-5.490939	0.0002
Test critical values	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

Null Hypothesis: Quarterly $\%(\boldsymbol{CNH} - \boldsymbol{CNY\ Spread})_t$ has a unit root		t-Statistic	Prob.*
Augmented Dickey-Fuller Test Statistic		-4.017301	0.0055
Test critical values	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

Null Hypothesis: Quarterly stock return has a unit root		t-Statistic	Prob.*
Augmented Dickey-Fuller Test Statistic		-6.460522	0.0000
Test critical values	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

Null Hypothesis: Quarterly Var(Spread) has a unit root		t-Statistic	Prob.*
Augmented Dickey-Fuller Test Statistic		-3.793457	0.0091
Test critical values	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

Null Hypothesis: Normalized capital fow has a unit root		t-Statistic	Prob.*
Augmented Dickey-Fuller Test Statistic		-6.236605	0.0000
Test critical values	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

Table 10. ADF Test for Volatility of Normalized capital flow

6.3.3. Granger Causality Test Result Analysis

6.3.3.1. VAR Lag Selection

From the indicators with "*" in Table 11, we get that the criteria of LR, FPE, AIC and HQ suggest choosing lag 1, only SC suggests choosing level value. Since 4 out 5 criteria suggest lag 1, we decide to chosse lag 1 to build VAR (1) to measure the correlations of the quarterly variables more accurately.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	471.4042	NA	2.65e-25	-42.40038	-42.15242*	-42.34197
1	501.0919	43.18209*	1.86e-25*	-42.82653*	-41.33875	-42.47606*
2	516.9209	15.82903	6.52e-25	-41.99281	-39.26520	-41.35027

*indicate lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Table 11. Lag pre-estimation

6.3.3.2. VAR Model Estimation

From the VAR (1) model estimation, the research obtains the following equations.

$$\%\Delta CNY_t = -0.513617 * \%\Delta CNY_{t-1} + 10.00048 * Var(Spread)_{t-1} - 0.172172 * \%(CNH - CNY\ Spread)_{t-1} - 0.004808 * SR_{t-1} + 0.000474 * CF_{t-1} + 8.19E - 06 + \varepsilon_t$$

$$Var(Spread)_t = 0.003635 * \%\Delta CNY_{t-1} + 0.187665 * Var(Spread)_{t-1} + 0.000345 * \%(CNH - CNY\ Spread)_{t-1} + 0.000262 * SR_{t-1} - (4.27E - 06) * CF_{t-1} + 8.24E - 06 + \varepsilon_t$$

$$\%(CNH - CNY\ Spread)_{t-1} = 0.169193 * \%\Delta CNY_{t-1} + 36.43112 * Var(Spread)_{t-1} + 0.248640 * \%(CNH - CNY\ Spread)_{t-1} + 0.018697 * SR_{t-1} + 0.001283 * CF_{t-1} + 0.001521 + \varepsilon_t$$

$$SR_t = -3.046128 * \%\Delta CNY_{t-1} - 374.5059 * Var(Spread)_{t-1} - 0.348404 * \%(CNH - CNY\ Spread)_{t-1} - 0.460617 * SR_{t-1} - 0.004641 * CF_{t-1} + 0.012694 + \varepsilon_t$$

$$CF_t = 186.4184 * \%\Delta CNY_{t-1} - 11442.59 * Var(Spread)_{t-1} + 78.93266 * \%(CNH - CNY\ Spread)_{t-1} + 18.77537 * SR_{t-1} - 0.234757 * CF_{t-1} + 0.102153 + \varepsilon_t$$

From the five equations in VAR (1) above, the adjusted coefficient of determination is 0.316304 for $\%\Delta CNY_t$, 0.115442 for Var (Spread), -0.067756 for $\%(CNH - CNY)_t$, 0.225549 for SR_t, and 0.040243 for normalized capital flow. The goodness to fit for the equations is not so large. It is because as the time period is long term, the influence of other factors beyond the 5 variables becomes more uncertain. The reversal coefficients do not appear since we choose 1 lag. By looking at the magnitude of the coefficients, we can see that the coefficients before Var (Spread) are large in all four equations, where the impact of Var (Spread) is negative to normalized capital flow and stock return, but positive to Var (Spread) itself, $\%\Delta CNY_t$ and $\%(CNH - CNY)_t$. That is, when the volatility of CNH-CNY increases, the percentage increase of CNY decreases (i.e. CNY depreciates), and stock performance is worse. And the more volatile the CNH-CNY spread is, the market probably expect more volatile market and the spread becomes more stable. In terms of the $\%(CNH - CNY\ Spread)$, since CNY depreciates, the spread is wider, when it is divided by a lower CNY, the value as a whole increases.

6.3.3.3. Granger Causality Test

Table 12 displays the results of Granger causality test. Compared with the previous models with high-frequency daily data sets, the quarterly data show even less granger causality relations among different pairs. If we determine the causality by looking at 5% level, only $\%(CNH - CNY\ Spread)$ Granger Causes $\%\Delta CNY$. No causality relationship appears among other pairs. Even if we look at the 10%, there are only 3 pairs out of 20 pairs presenting granger causality: $\%(CNH - CNY\ Spread)$ Granger Causes $\%\Delta CNY$, Var (Spread) Granger Causes stock return, Normalized CF Granger Causes Var (Spread). The difference may result from the time structure. The previous daily data show the instant impact of variable on others. The lasting time for the causality is short in short-term time period. However, the quarterly data shows the long-term causality relationship, which detects fewer pairs that maintain causality as time goes on.

Normalized CF Granger Causes Var (Spread) is reasonable since frequent capital flow movement indicate the unstable market, which causes fluctuating CNH-CNY spread as volatility. Var (Spread) Granger Causes stock return also has the implication that when CNH-CNY spread become more volatile, stock performance changes correspondingly, either because of the additional investment opportunity or because of the policy restrictions. However, since the sample size of the observations is small. It remains a myth whether there exists the causal link that capital flow movement causes the volatility of CNH-CNY spread, which then causes the change in stock return? Or, whether the influence of capital flow movement is significant enough to cause the stock performance? These are the questions need further exploration.

Null Hypothesis	Obs	F-Statistic	Probability	Result
$\%\Delta CNY$ does not Granger Cause $\%(CNH - CNY\ Spread)$	23	0.01077	0.9184	Accept H_0
$\%(CNH - CNY\ Spread)$ does not Granger Cause $\%\Delta CNY$	23	8.66617	0.0080	Reject H_0
Stock return does not Granger Cause $\%\Delta CNY$	23	0.09998	0.7551	Accept H_0
$\%\Delta CNY$ does not Granger Cause stock return	23	0.69460	0.4144	Accept H_0
Stock return does not Granger Cause $\%(CNH - CNY\ Spread)$	23	2.6E-05	0.9960	Accept H_0
$\%(CNH - CNY\ Spread)$ does not Granger Cause stock return	23	0.11664	0.7363	Accept H_0
Stock return does not Granger Cause Var(Spread)	23	2.00319	0.1724	Accept H_0
Var(Spread) does not Granger Cause stock return	23	3.68354	0.0693	Reject H_0
Var(Spread) does not Granger Cause $\%\Delta CNY$	23	0.04352	08369	Accept H_0
$\%\Delta CNY$ does not Granger Cause Var(Spread)	23	2.45141	0.1331	Accept H_0
Var(Spread) does not Granger Cause $\%(CNH - CNY\ Spread)$	23	0.21087	0.6510	Accept H_0
$(CNH - CNY\ Spread)$ does not Granger Cause Var(Spread)	23	0.53630	0.4725	Accept H_0
Normalized CF does not Granger Cause $\%\Delta CNY$	23	1.52298	0.2315	Accept H_0
$\%\Delta CNY$ does not Granger Cause Normalized CF	23	0.06305	0.8043	Accept H_0
Normalized CF does not Granger Cause $\%(CNH - CNY\ Spread)$	23	1.49711	0.2353	Accept H_0
$\%(CNH - CNY\ Spread)$ does not Granger Cause Normalized CF	23	1.42418	0.2467	Accept H_0
Normalized CF does not Granger Cause stock return	23	2.15325	0.1578	Accept H_0
Stock return does not Granger Cause normalized CF	23	0.59333	0.4501	Accept H_0
Normalized CF does not Granger Cause Var(Spread)	23	3.61690	0.0717	Reject H_0
Var(Spread) does not Granger Cause Normalized CF	23	0.50880	0.4839	Accept H_0

Table 12. Granger Causality Test among Variables

6.3.4. Impulse Response Function Analysis

The Figure 7 below analyzes how each variable in this VAR reacts to one S.D. innovation on each dependent variables. Interesting reversal patterns occur in the response of each variable. The responses act periodically every year with 4 quarters. In contrast, the responses of $\%\Delta CNY$, normalized capital flow and Var(Spread) are more apparent with tooth like patterns.

If the graphs show right information, the reversal pattern may result from a seasonal effect. We then analyze the response of the variables in the first year. An innovation on $\%\Delta CNY$ itself, Var(Spread) and normalized capital increases $\%\Delta CNY$ in the following half year, then reverse between the positive and negative impact quarterly. An innovation on stock return have little impact on $\%\Delta CNY$, but increases the $\%\Delta CNY$ in the third quarter, then reverse the impact quarterly. An innovation on $\%(CNH - CNY\ Spread)$ have the opposite effect of $\%\Delta CNY$ itself, Var(Spread) and normalized capital.

An innovation on $\%(CNH - CNY\ Spread)$ and stock return increases capital inflow in the following half year, then reverse between the positive and negative impact quarterly. An innovation on capital flow increases capital inflow in the following quarter, then reverse between the positive and negative impact quarterly. An innovation on Var (Spread) promotes capital outflow within the first three quarters, then switch between reducing capital outflow and increasing capital outflow quarterly. An innovation on $\%\Delta CNY$ increases inflow in the first quarter, then follows the opposite pattern from the ones with shocks to other 4 variables. An innovation on normalized capital inflow reduce CNH-CNY volatility in the first 3 quarters and reverse the impact quarterly, which is opposite from the effects of shocks on other variables.

However, due to the lack of a large data size, there may exist estimate error. There are large positive and negative VAR coefficients—a shock to variable A causes a second variable

B to go up (i.e. positive coefficient on lagged A in B equation), but this then causes the first variable to go down (negative coefficient on lagged B in A equation). We can take the $\%\Delta CNY$ as variable A, and $\%(CNH - CNY\ Spread)$ as variable B for example. Then we need to investigate whether contemporaneous correlation exists in the error terms. In this case, the research looks further into the residual correlation among the variables in VAR (1), which is listed in Table 13.

	$\boldsymbol{\%\Delta CNY}$	***Normalized CF***	$\boldsymbol{\%(CNH - CNY\ Spread)}$	***Stock Return***	***Var (Spread)***
$\boldsymbol{\%\Delta CNY}$	1.000000	0.242158	-0.417652	-0.075382	0.206071
Normalized CF	0.242158	1.000000	-0.016808	-0.170530	-0.154363
$\boldsymbol{\%(CNH - CNY\ Spread)}$	-0.417652	-0.016808	1.000000	-0.227671	0.302032
Stock Return	-0.075382	-0.170530	-0.227671	1.000000	0.111494
Var (Spread)	0.206071	-0.154363	0.302032	0.111494	1.000000

Table 13. Residual correlation matrix among 5 Variables

By the residual correlation matrix, we can see that residual correlation between $\%\Delta CNY$ and $\%(CNH - CNY\ Spread)$ is -0.417652. The negative may tell the potential reason that a shock on $\%(CNH - CNY\ Spread)$ drives $\%\Delta CNY$ down, but the decrease in $\%\Delta CNY$ promotes the $\%(CNH - CNY\ Spread)$ in following period as the blue and green lines shown. However, there also exists some counterexamples for the residual correlation. For instance, if we look at $\%\Delta CNY$ and stock return, although the residual correlation is negative, on shock on each variable will both have positive impact to $\%\Delta CNY$. Moreover, the correlation coefficients in the equations are the same, meaning the change in the error is insignificant in this case. Similar inconsistence between the residual correlation and the impact revealed in the RIF also occurs between the variables of capital flow and CNH-CNY spread volatility.

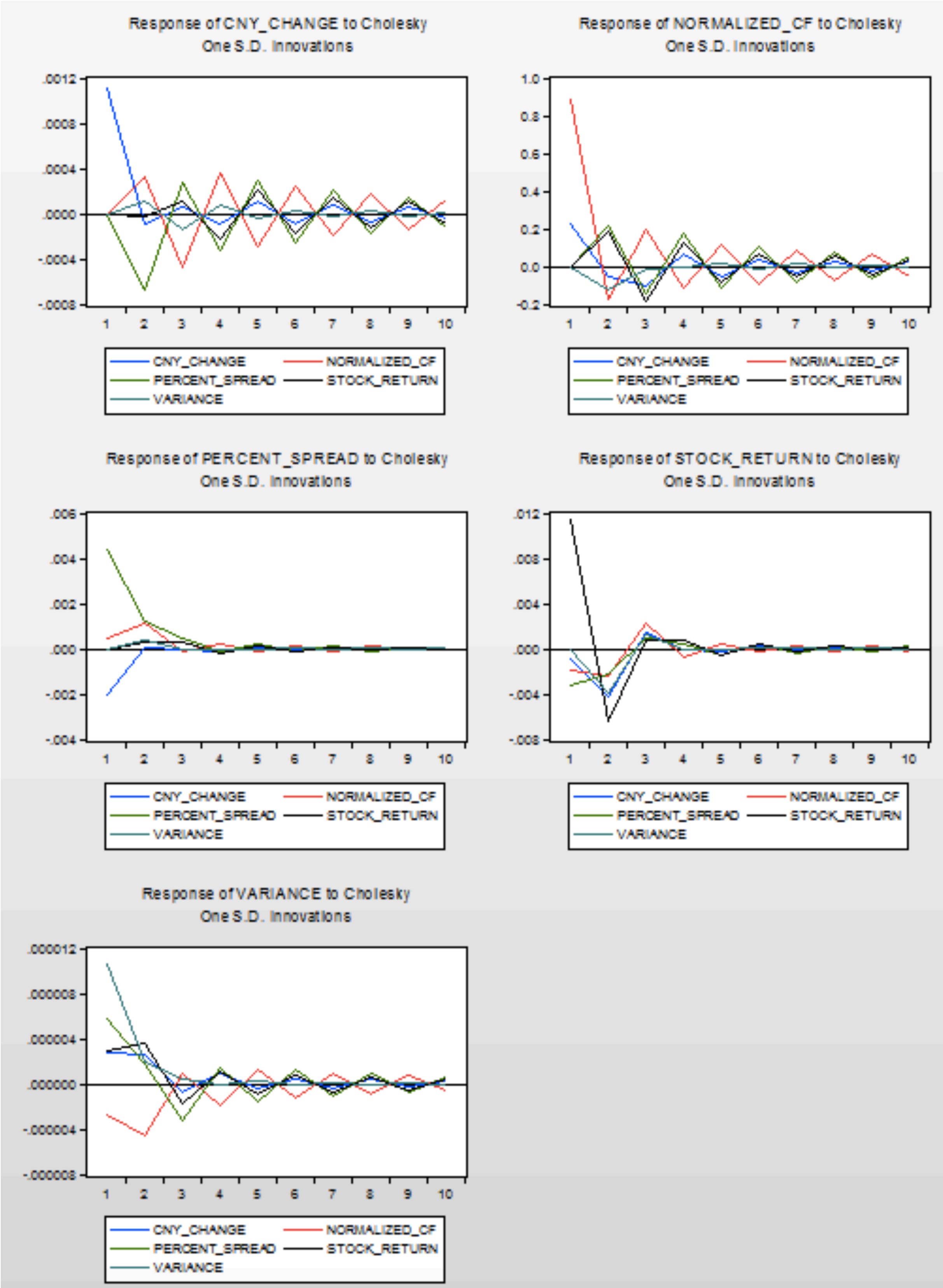
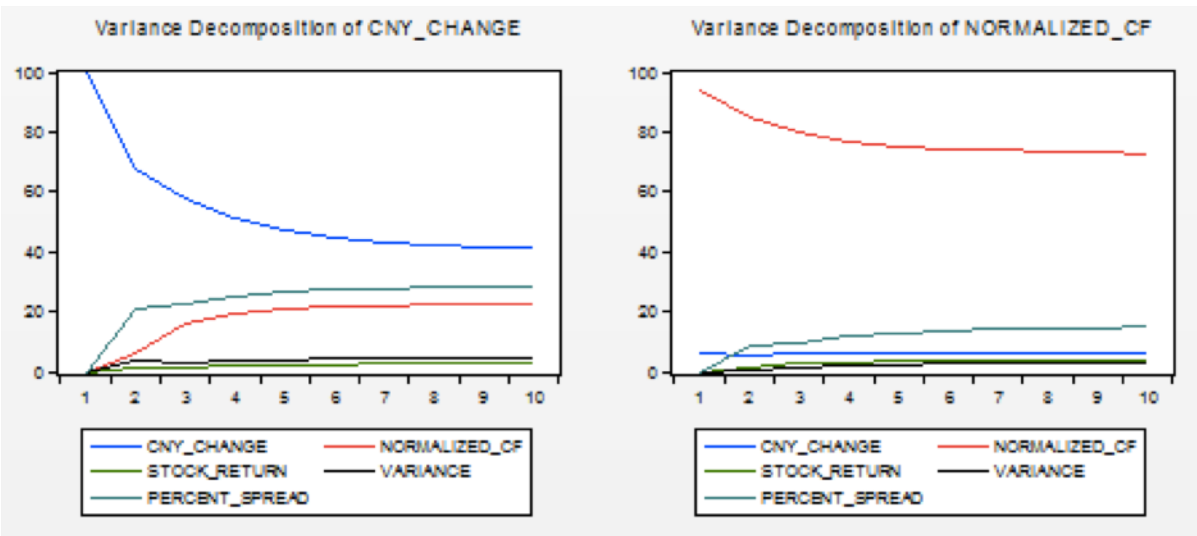


Fig.7 IRF of the 5 quarterly variables

6.3.5. Variance Decomposition Analysis

The Figure 8 shows the contribution of each type of shock to the forecast error variance. If that the effect of estimation error is not so big, then the error variance of $\%\Delta CNY$ is largely contributed by itself, starting from 100% and diminishing along the time which finally restricted the level around 40%. In comparison, the contribution of the $\%(CNH - CNY\ Spread)$ and capital flow increases fast in the first two time periods with the $\%(CNH - CNY\ Spread)$ contributing 30%, and capital flow contributing around 22%. As for the error variance of capital flow, stock return and CNH-CNY spread volatility, their previous performance mainly contribute to the forecast error variance from 65% to 90%. In the case of $\%(CNH - CNY\ Spread)$, almost 50% to 58% of the variance is contributed by itself. CNH-CNY spread volatility contributes 20% to 23%, $\%\Delta CNY$ contributes 17% to 20%, and the stock return and capital flow contribute about 8% as time goes by.

However, the figure should not be over-interpreted. While the graphs are much more interesting, the VAR coefficients themselves are generally not statistically significant. That said, there could be stories about (1) spread and capital flow becoming important for the exchange rate, and (2) even spread becoming important for capital flow. According to Exhibit 20, we can see that there exists some significant correlations among variable shocks.



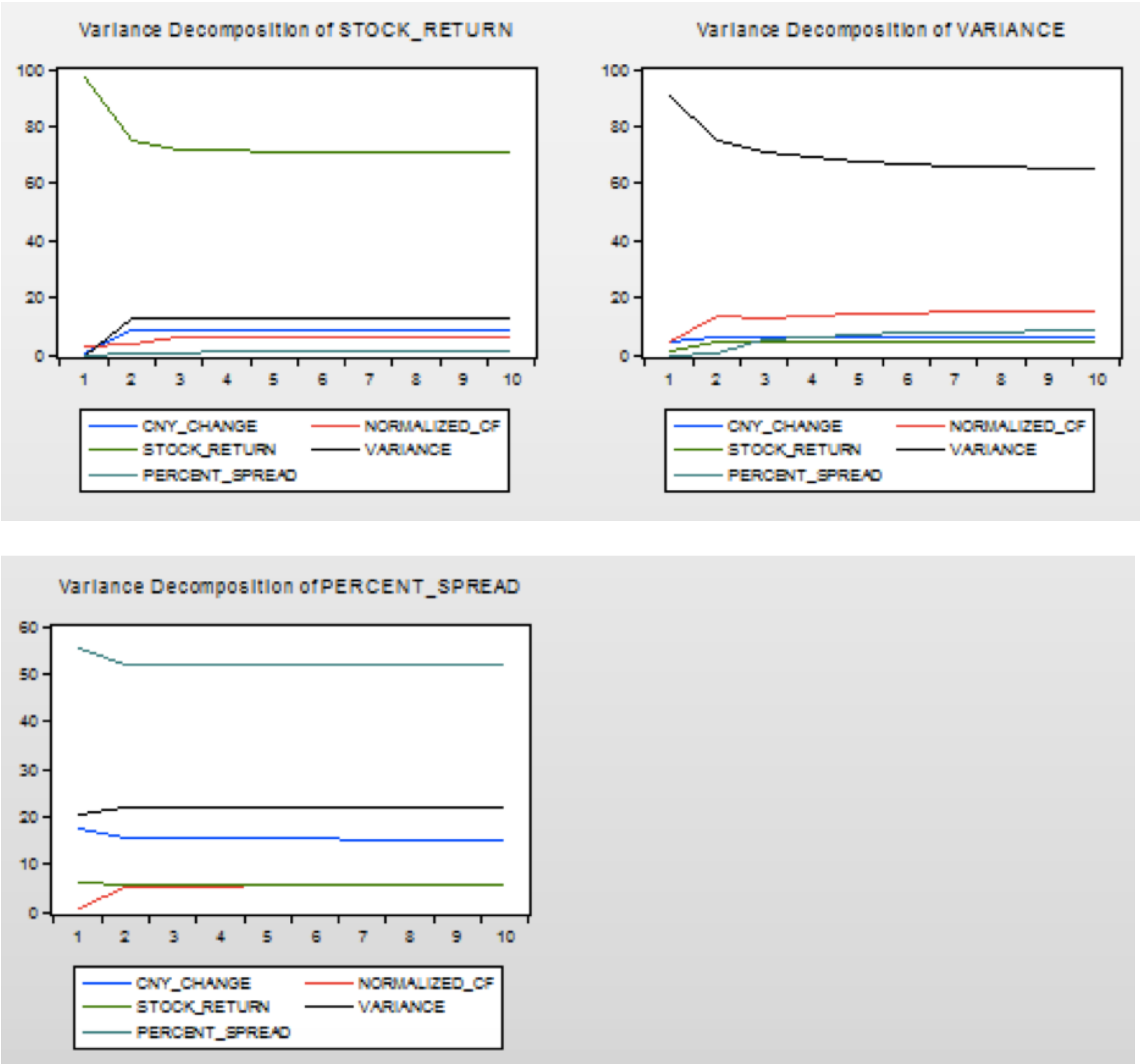


Fig. 8 Variance decomposition of the 5 quarterly variables

Conclusions and Implications

In this thesis, we examine the interactions between RMB exchange rates and stock return based on the evidence of CNY, CNH-CNY spread, CNH-CNY spread volatility and capital flow change. Some similar patterns occur in both the 3 and 4 variable VAR models. The CNY exchange rate changes are predictable by both spreads and stock returns, which proves Branson's portfolio theory that stock returns somehow cause the CNY movements. The granger causality test also shows that stock returns are also predictable using spread. And the percent spread itself is very persistent, that is, it depends heavily on its lagged value. This result is a bit different from Dornbusch's flow oriented model that suggests the strong causal linkage from the exchange rate[16] to stock performance. But in a broader sense, the bidirectional causal relationship between stock return and exchange rate measurements exists.

Since both the spread and stock returns as "market" variables[17] and the CNY as a variable controlled by the PBOC, then we can imply the result that, CNH-CNY spread has bigger predictability in stock market than CNY in China's case. Although CNY exchange rate changes do not vary too much along the time under PBOC's exchange rate control, we still can use "market" variables as predictors. When the CNH-CNY spread widens, or when the volatility of CNH-CNY spread becomes stronger, it means the true value of RMB in market fluctuates a lot, since the direction that capital goes on shore and off shore reflects market's expectation on the future value of CNY. However, the volatility of CNH-CNY spreads predicts only itself surprisingly. But the volatility is clearly predictable by all the other variables. This may be because the impact of spread volatility is too small to be detected in terms of its economic value. Although China is trying to internationalize the RMB, the restrictions on the exchange rate fluctuation have not been removed completely, implying only small magnitude of volatilities can be detected in China's exchange market.

The high frequency impulse-response results suggest similar results as that of variance decomposition: in general, it is the shocks to the variable itself that determine the future path. Shocks to CNY change and the stock return die out fast, which is reasonable since these variables are close to independent across time. However, volatility and spread are persistent. The effect of lagged spread on the CNY change shows up as they should. The variance decomposition at high frequencies does not show dynamic interaction among the variables, since they mainly affected by themselves. Presumably this is because while there are

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[16] Here the paper assumes the "exchange rate" stands for the international price of domestic currency (i.e, CNY in this case).

[17] Here, the "market variables" stand for the variables quantities determined in the market.

statistically significant Granger causality effects across variables, these cross-variable effects are small in economic magnitude, and therefore swamped by the shocks to the variable itself.

As for the low-frequency quarterly data, less Granger causality relationship appears among the variable pairs. This may result from the long-term time structure and the limit of quarterly data. The analysis for RIF and variance decomposition are much trickier although the discovery of reversal patterns is surprising. From the results, we may imply that, the capital flow acts as a channel between the mechanisms. When CNY depreciates, investors expect CNH to appreciate even more in the future. They turn to invest in foreign market with capital flowing out. The lack of investment further dries the stock return. However, because the sample size of the data sets is still small and the significance of the correlation in VAR (1) is small, the paper cannot deny the existence of estimation error as we observe some significance in the residual correlation matrix.

In future research, comprehensive analysis of the residual correlations among the stock return and exchange rate measurements would provide more information to explain the reversal patterns occurred in the impulse response function test of low frequency data. Because the population of quarterly national capital flow data after the new establishment of CNH market is too small, it requires longer time horizon to investigate the interactions of the rates in the long run. To examine more time-specific linkages, further research can be conducted to examine dynamics between CNY, CNH-CNY spread, capital flow and stock return by separating the whole time horizon into multiple stages based on major exchange reform events. The strong predictability of CNH-CNY on other parameters such as stock return and future movements of CNY provides an avenue for deeper research on the potential arbitrage opportunity of investment across financial markets. As for the CNH-CNY spread volatility, although the current implication is limited, but it is likely to have stronger prediction power with China’s effort in liberalizing the CNY exchange rate.

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Appendix

Exhibit 1. Overview of historical movement of CNY and SSE Composite Index

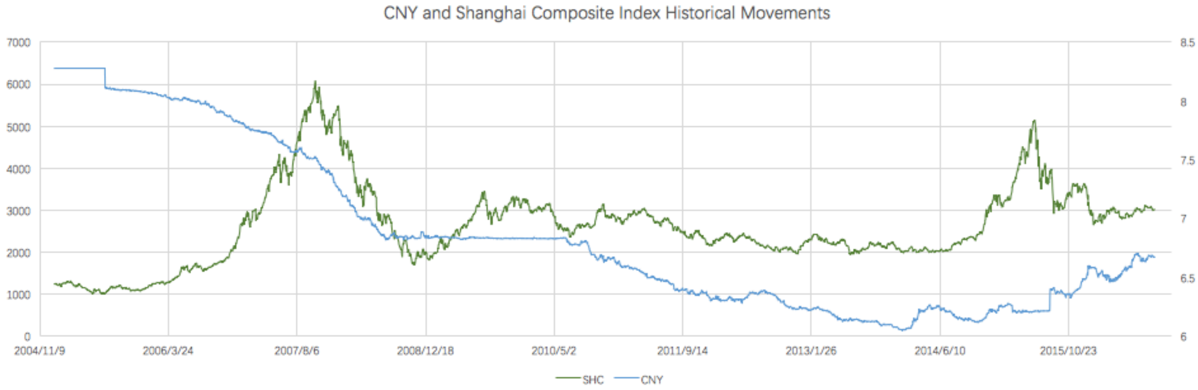


Exhibit 2. Overview of historical movement of CNY and CNH

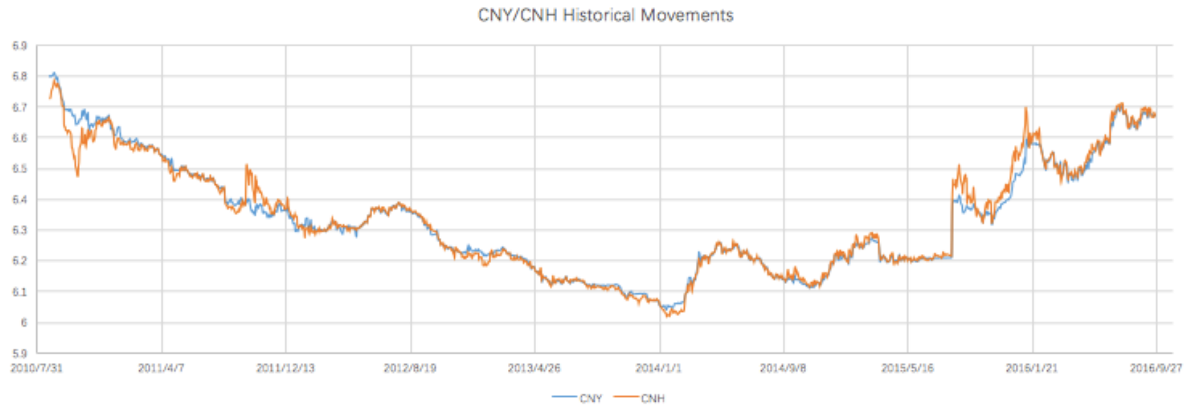


Exhibit 3. Overview of historical movement of CNY and SSE Composite Index

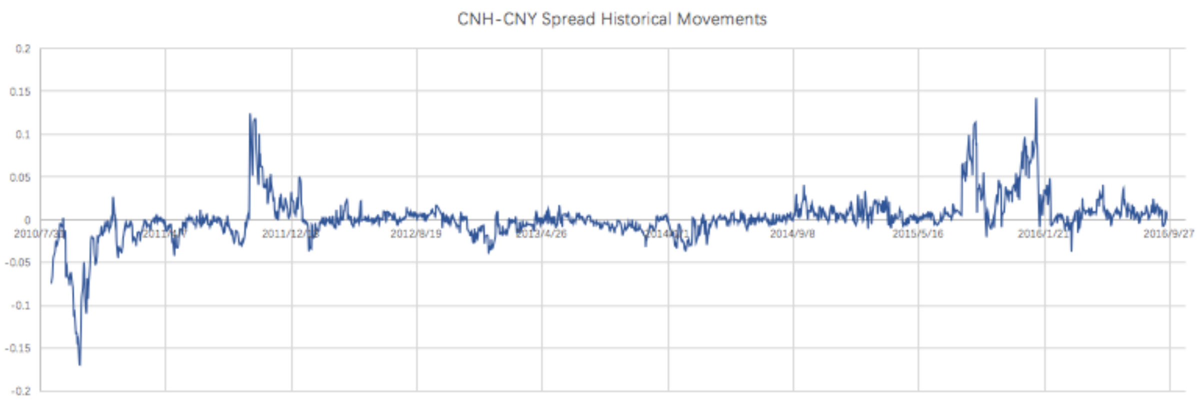
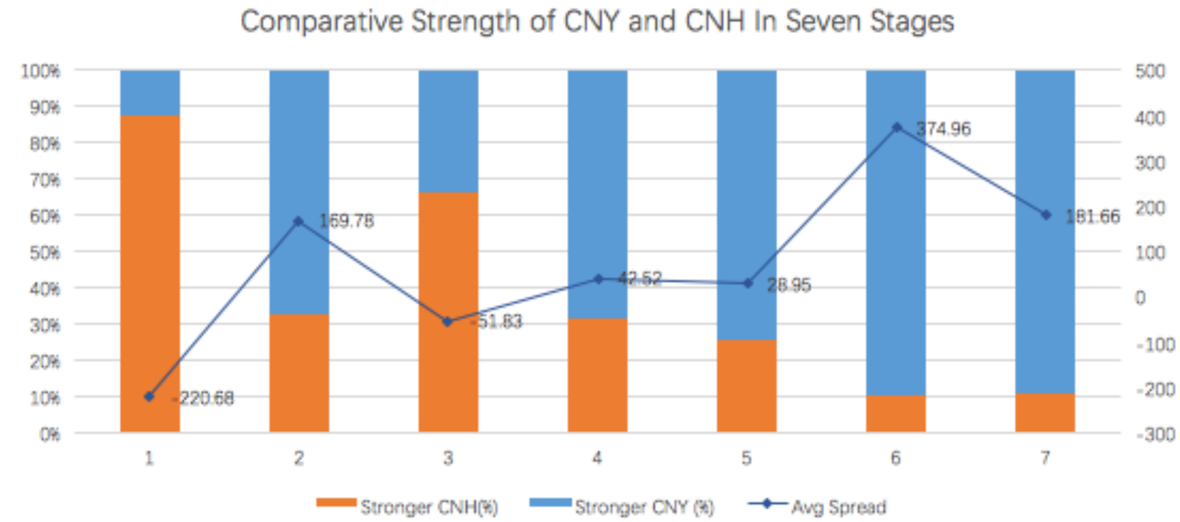


Exhibit 4. Comparative strength of CNY and CNH in seven historical stages



Stage		Major Event
1	08/23/2010 – 09/22/2011	The primary development of CNH market
2	09/23/2011 – 04/13/2012	BOCHK cross-border clearing amount is exhausted
3	04/14/2012 – 03/14/2014	Central Bank relaxed floating band of the CNY-USD from 0.5% to 1%
4	03/17/2014 – 04/15/2015	Central Bank relaxed floating band of the CNY-USD from 1% to 2%
5	04/16/2015 – 08/10/2015	Prime Minister Li Keqiang declared to stabilize the CNY
6	08/11/2015 – 11/30/2015	"8.11 Reform": improve the RMB middle price quotes mechanism
7	11/31/2015 – 09/22/2016	IMF decided to add RMB to Special Drawing Rights (SDR) Basket

Exhibit 5. National capital flow and stock price movement in China

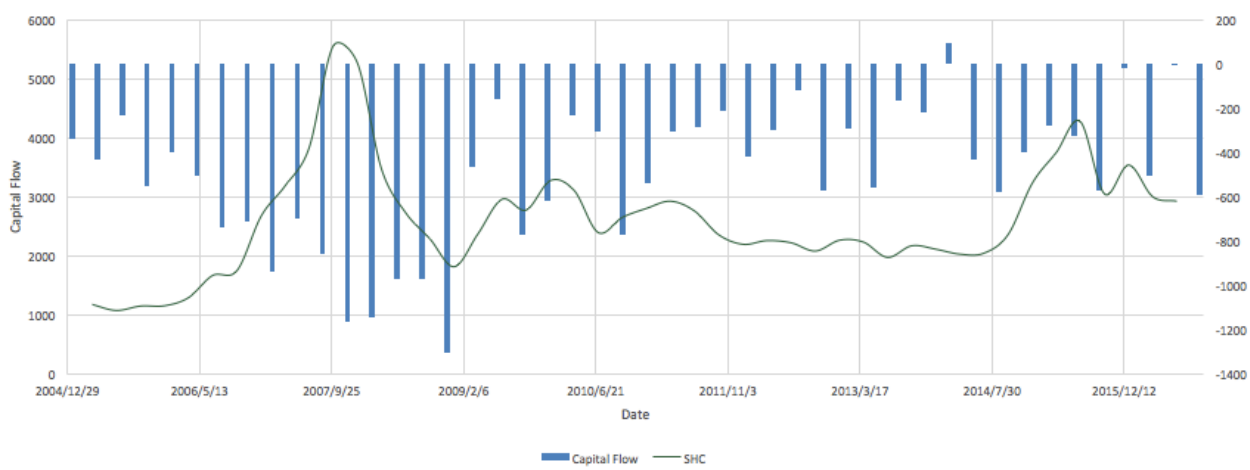


Exhibit 6. GARCH (1,1) Test on percentage change of CNH-CNY spread

Dependent Variable: PERCENT_SPREAD
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 03/13/17 Time: 10:38
Sample: 8/23/2010 9/22/2016
Included observations: 1562
Convergence achieved after 44 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.34E-05	0.000549	0.151753	0.8794
AR(1)	0.934866	0.004490	208.2093	0.0000
SIGMASQ	2.14E-06	3.06E-08	70.07494	0.0000

R-squared	0.870849	Mean dependent var	0.000174
Adjusted R-squared	0.870683	S.D. dependent var	0.004076
S.E. of regression	0.001466	Akaike info criterion	-10.20956
Sum squared resid	0.003350	Schwarz criterion	-10.19928
Log likelihood	7976.667	Hannan-Quinn criter.	-10.20574
F-statistic	5256.069	Durbin-Watson stat	2.214409
Prob(F-statistic)	0.000000		

Inverted AR Roots	.93

Heteroskedasticity Test: ARCH

F-statistic	28.94580	Prob. F(5,1551)	0.0000
Obs*R-squared	132.8886	Prob. Chi-Square(5)	0.0000

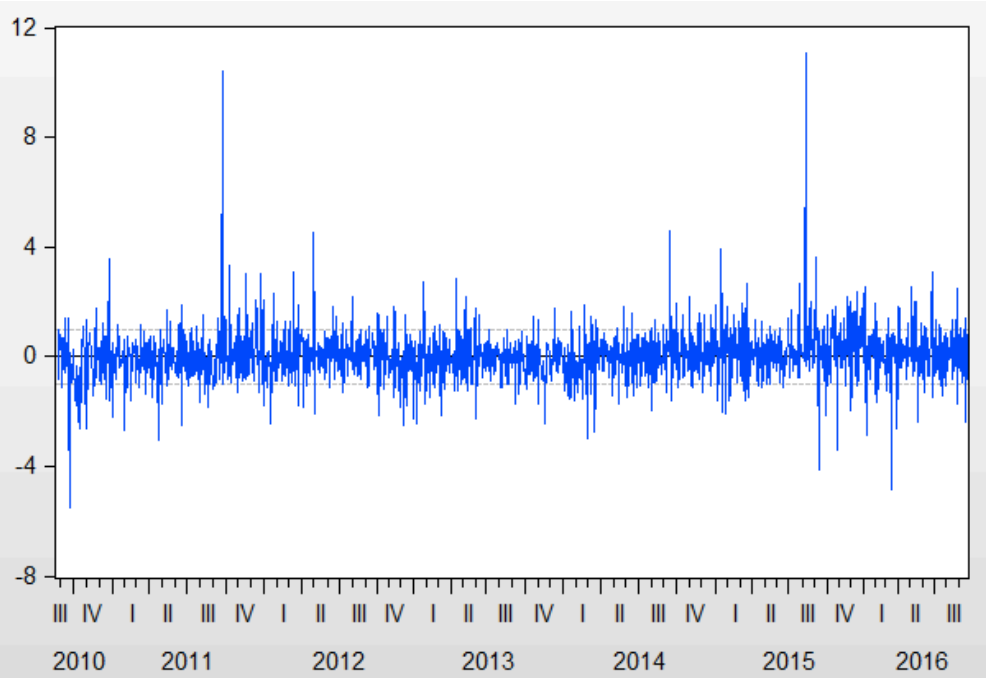
Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 03/13/17 Time: 04:46
Sample (adjusted): 8/30/2010 9/22/2016
Included observations: 1557 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.17E-06	2.06E-07	5.667955	0.0000
RESID^2(-1)	0.184391	0.025331	7.279197	0.0000
RESID^2(-2)	0.121483	0.025641	4.737838	0.0000
RESID^2(-3)	-0.017342	0.025821	-0.671642	0.5019
RESID^2(-4)	0.097740	0.025640	3.812046	0.0001
RESID^2(-5)	0.068619	0.025305	2.711656	0.0068

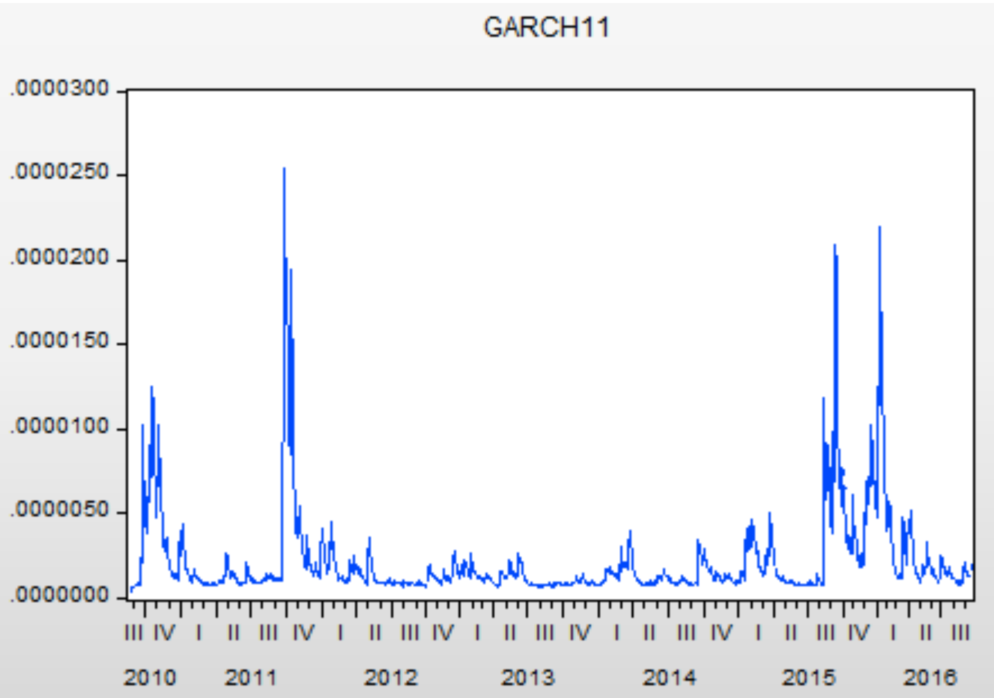
R-squared	0.085349	Mean dependent var	2.14E-06
Adjusted R-squared	0.082401	S.D. dependent var	7.64E-06
S.E. of regression	7.32E-06	Akaike info criterion	-20.80775
Sum squared resid	8.31E-08	Schwarz criterion	-20.78713
Log likelihood	16204.83	Hannan-Quinn criter.	-20.80008
F-statistic	28.94580	Durbin-Watson stat	2.009246
Prob(F-statistic)	0.000000		

Exhibit 7. Graph visualization of percentage change of CNH-CNY spread

Plot of percentage change of CNH-CNY spread[18]



Volatility of percentage change of CNH-CNY spread
based on the GARCH (1,1) model



[18] The plot of percentage change of CNH-CNY spread shows the clustering volatility pattern which fits the assumption of GARCH models.