1. THE RISK CONTAGION EFFECT OF RETURN VOLATILITY BETWEEN CHINA'S OFFSHORE AND ONSHORE FOREIGN EXCHANGE MARKET

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Abstract

The main objective of the paper is to study the risk contagion effect of return volatility between China's offshore and onshore foreign exchange market. Based on the formation mechanism of offshore RMB, we divide the offshore RMB exchange rate indices into three stages. The VAR model is applied to analyze the impact direction, extent and duration of the return volatility. GARCH-Granger overall risk contagion model and Contagion-MGARCH time-varying risk contagion model are applied for the static and dynamic analysis on the risk transmition between the offshore and onshore markets. The empirical conclusions are as follows: the direction and the extent of the risk contagion effect of return volatility between China's offshore and onshore foreign exchange market.is quite different as time varys. The transmission channels of financial risks between the offshore and onshore markets vary in the different stages. Among all three stages, offshore foreign market has a significant contagion effect to the onshore foreign exchange market. Compared with the overall contagion studies, the time-varying method shows a more intuitive and dynamic process of risk contagion effect. The results provide a reference for the construction of the offshore RMB financial market in the internationalization process.

Keywords: risk contagion effect; impulse response; VAR model; overall contagion model; time-varying contagion model

JEL Classification: F31; F41; G15; G21

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1. Introduction

With globalization and integration of the world economy, the relation between financial markets is closer. The increasing scale of international financial exchange, capital and financial service flow has brought more risks to the domestic financial market. The offshore financial market is an effective channel for financial internationalization and provides a financial buffer to the onshore market.

In recent years, Hong Kong offshore financial market has begun to take shape. However, it is still in its infancy, and the market supervision and risk prevention system need to be perfected. The previous studies are mainly from the macro qualitative analysis aspects, while the quantitative research on the risk transmission mechanism between the offshore and onshore foreign exchange market is lacked. China is at a critical stage of the development of the offshore RMB financial market. There are few research focusing on the risk contagion mechanisms for the offshore RMB foreign exchange market. This paper made a detailed empirical study in this field, and providing theoretical support and policy suggestions to the offshore market.

The major contribution of the empirical study is analyzing the impulse volatility of the return on the offshore and onshore RMB foreign exchange market from a static point of view, including the direction and extent, and measuring the contagious risk on the return volatility between the offshore and inshore RMB foreign exchange markets from a dynamic point of view, revealing the direction and time-varying characteristics. In this study, the VAR model, the overall risk contagion model and time-varying risk contagion model are applied to analyze the risk transmitting of return volatility between offshore and onshore RMB foreign exchange market. It proves the existence of the risk contagion effect between the offshore and onshore RMB markets. And in the end, policy suggestions are given regarding to the RMB offshore financial market and China's financial internationalization process.

2. Literature Review

The main interests of foreign scholars are concentrated on the risk control and the market function and operation mode of offshore financial market. Walter (1998) focused on tax havens offshore financial center construction and tax policy. Kwaw (2001) analyzed the offshore financial market supervision from the financial crime perspective. Rawlings (2005) pointed out that the market regulation and supervision gave positive influence to the economic profitability. Coffey *et al.* (2009) noted that international companies are gradually abandon the dollar denominated assets and invest in the foreign exchange swap market due to dollar shortage and the financial crisis-prone background. Hampton *et al*. (2010) explored the offshore financial centers and tax havens in the island economies. Rossi and Jackson (2011) analyzed the location advantages of Hong Kong offshore financial center and its driving force to RMB internationalization. Palan and Nesvetailova (2013) studied the correlation between the offshore financial centers and shadow banking system and the impacts to the supervision of global financial system. Haberly and Wójcik (2014) found that the offshore FDI has brought similar effect for both developed and developing countries. Buckley *et al*. (2015) studied the characteristics of global FDI flows from the perspective of geography and finance.

The studies on the functions and operations mechanism of the offshore market are abundant. Giddy (1979) concluded that the offshore interest rates are more sensitive and adjusted more quickly than the onshore interest rate. Kaen and Hachey (1983) pointed out that there was a one-way leading role of the onshore to the offshore foreign exchange rate for both dollars and pounds in the 1970s. Same result was published by Hartman (1984). Rawlings (2005) noted that the study was meaningful from the micro perspective other than the macro perspective for decreasing the transaction cost in the offshore markets. Williams (2012) suggested that the offshore financial market was very important for local government in terms of revenue and employment. Saadma and Vaubel (2014) noted that Eurodollar was the result of financial innovation and the competition from the two financial centers. Sidortsov and Sovacool (2015) studied the relationship between the offshore market of US dollar and onshore oil and gas market, clarifying the interaction between the two.

The early studies of Chinese scholars are mainly focused on the introduction of the offshore financial markets in the developed countries. Zuo and Wang (2002) gave general recommendations to support establishing the offshore financial market. Xia and Chen (2004) noted that China's offshore finance market has significant impacts on attracting foreign investment, promoting finance specialization and globalization. Li and Yu (2005) pointed out that the generation of offshore financial markets is based on the globalization and liberalization of the economy. Zhu (2006) noted the importance of offshore financial supervision as the risks of offshore financial market have great influence on the stability of the financial system. Gao (2008) reviewed the history of offshore financial market and defined the concept, content, features and extension of the offshore financial market. Liu (2010) studied the path choice of establishing the financial center, and gave suggestions on the construction of the offshore financial market in China. Tu (2011) discussed the risk of offshore financial market, suggesting that sound risk regulation can reduce the risk in the offshore financial market. Wang (2012) analyzed the development of the world's financial markets, and conducted some experience for China based on the case study of the European money market. Zhang (2013) noted that multi-distributions mode were more suitable for China's offshore financial market. Yan *et al*. (2014) chose four different types of offshore financial market, namely Hong Kong, Japan, Singapore FTA and the Cayman Islands and studied their construction and operation experience, providing a reference for offshore business in Shanghai Free Trade Zone. Wu and He (2014) introduced the development of financial contagion theory from financial crisis. They summarized international transmission channels of financial risks and indicated future directions for research on financial contagion. Zhou and He (2015) proposed a time-varying contagion model based on high frequency data, taking the metal futures of SHFE as an example. They found the effective approach to control the risk contagion effect is to timely deal with the original market and the risk contagion effect combining the time-varying and high frequency factors is inversely proportional to price volatility. Zhao and Zhang (2016) constructed risk indices respectively of exchange rate risk in the foreign exchange market, liquidity risk in the monetary market and index risk in the stock market and analyzed the risk contagion effect within different sub-markets. Lu and Meng (2016) indicated the definition, classification of the offshore financial markets, highlighting the positive effects and risks of these markets through illustrating the relevant development experience of Europe, US, Japan and Thailand.

The previous research is mainly on the overall development of offshore financial market, providing some experiences on the establishment and development for China's offshore financial market. There are few research focusing on the risk contagion risk precaution. Besides, more qualitative analysis and theoretical suggestions are made rather than a complete rigorous quantitative research. There are even less research focusing on the risk contagion mechanisms for the offshore RMB foreign exchange market. This paper studies the risk contagion effect of return volatility between China's offshore foreign exchange market (Hong Kong foreign exchange market) and onshore foreign exchange market. Besides, we put forward supervision enlightenment for preventing risk from the perspective of financial markets' overall regulation.

3. Data and Methodology

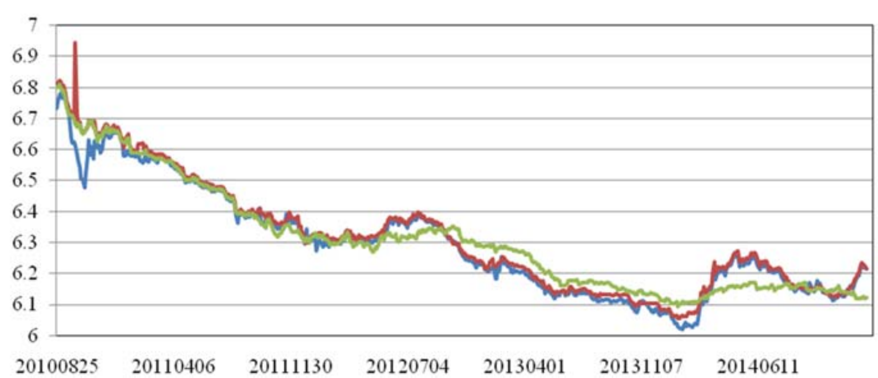
3.1 Indices Selection

In this study, the daily closing price of the spot exchange rate of offshore RMB against US dollar is selected to represent the return volatility of RMB offshore foreign exchange market (CNH market). Data resource is the Bloomberg website. In the onshore foreign exchange market, daily cash selling rate/telegraphic transfer selling rate, referred to as CNY1, is chosen as a representative index for the return volatility. Data resource is the Financeifeng. Considering political influence, the daily reference rate of RMB against the US dollar in the interbank foreign exchange market is chosen, referred to as CNY2, representing the return volatility of the onshore foreign exchange market. The data is collected from the State Administration of Foreign Exchange. Logarithmic method is applied to reduce heteroscedasticity.

Data duration is from August 25, 2010 to December 31, 2014. The overlapping part between CNH, CNY1 and CNY2 are chosen, for a total of 555 set of observations. It is divided into three stages according to the changes in the formation mechanism of RMB exchange rate. Stage 1 is August 25, 2010 to June 26, 2011, when the CNH market in Hong Kong was preliminarily framed with the milestone that Hong Kong banks and other financial institutions were allowed to invest in RMB into the mainland interbank bond market. BOCHK rate was taken as CNH rate. Stage 2 is June 27, 2011 to April 13, 2012. CNH fixing was launched by Hong Kong Capital Markets Association. Stage 3 is April 14, 2012 to December 31, 2014.The People's Bank of China expanded the floating range of RMB against US dollar from 5‰ to 1% per day, making CNY market exchange rate more flexible. The prices of RMB in both the CNH market and CNY market is shown in Figure 1: the closing rate of RMB against US dollar (blue), cash selling rate/telegraphic transfer selling rate (red) and the middle rate of RMB against the US dollar the interbank foreign exchange market (green).

Figure 1

The RMB Fluctuation in the CNH and CNY Market, 8/25/2011-12/31/2014



Source：Bloomberg, The State Administration of Foreign Exchange.

3.2 Data Analysis

The descriptive statistics is shown in Table 1. CNH, CNY1 and CNY2 have passed the stationary test. The ADF test results suggesting stable. Higher-order serial correlation on standardised residuals and squared standardised residuals is tested by Ljung-Box Q test with 5 and 15 lags, respectively.

Table 1

The Descriptive Statistics

Variables		Mean	Standard Deviation	Skewness	Kurtosis	JB Statistics	Q(5)	Q(15)	ADF
1	CNH	-0.0004	0.0028	0.348	5.594	31.854 ***	6.680	16.469	-9.435***
	CNY1	-0.0005	0.0051	0.821	41.517	6564.268***	18.784	22.873	-11.220***
	CNY2	-0.0005	0.0014	-0.1028	3.509	1.331 ***	3.337	7.014	-8.981***
2	CNH	-0.0002	0.0022	0.195	4.834	15.077 ***	11.219	42.810***	-13.745***
	CNY1	-0.0002	0.0016	-0.802	4.256	17.814 ***	2.537	9.164	-11.270***
	CNY2	-0.0003	0.0014	0.179	4.581	1.999 ***	5.502	9.609	-9.8139***
3	CNH	0.0000	0.0018	0.748	6.491	207.273***	13.375**	33.236***	-21.203***
	CNY1	0.0000	0.0014	0.437	7.217	266.637 ***	5.629	39.006***	-17.995***
	CNY2	-0.0001	0.0010	-0.353	4.633	45.515 ***	4.930	18.864	-18.963***

****、** respectively denote the original hypothesis was rejected at the 1%, 5% significance level. Q(5), Q(15) are the statistics of the Ljung-Box test.*

In order to avoid spurious regression, cointegration test is applied for CNH, CNY1 and CNY2. According to Table 2, there is a co-integration relationship between these indices, suggesting a stable equilibrium relationship between CNH and CNY1, and CNH and CNY2. This laid the foundation for the following empirical study.

Table 2

The Cointegration Test for CNH, CNY1 and CNY2

Time	Index	Null hypothesis	Eigenvalue	T value	5% critical value	P value
8/25/2010-6/26/2011	$CNH \leftrightarrow CNY1$	None	0.3523	40.3262	25.4947	0.0341
		At most 1	0.1504	16.4565	18.4147	0.2061
	$CNH \leftrightarrow CNY2$	None	0.2386	47.2551	25.4947	0.0182
		At most 1	0.1774	14.7186	18.4147	0.1467
6/27/2011-4/13/2012	$CNH \leftrightarrow CNY1$	None	0.2926	51.4289	25.4947	0.0485
		At most 1	0.1636	17.5037	18.4147	0.2659
	$CNH \leftrightarrow CNY2$	None	0.2809	57.8391	25.4947	0.0364
		At most 1	0.2293	15.5214	18.4147	0.1642
4/14/2012-12/31/2014	$CNH \leftrightarrow CNY1$	None	0.3082	174.6354	25.4947	0.0187
		At most 1	0.1351	13.3666	18.4147	0.4196
	$CNH \leftrightarrow CNY2$	None	0.1901	122.1294	25.4947	0.0482
		At most 1	0.1378	17.4267	18.4147	0.3647

3.4 Model Design

Variance decomposition and impulse response are used in this study. We build the VAR model as is shown in Equation 1.

$$\begin{pmatrix} CNH \\ CNY_1 \\ CNY_2 \end{pmatrix}_t = C + A_1 \begin{pmatrix} CNH \\ CNY_1 \\ CNY_2 \end{pmatrix}_{t-1} + A_2 \begin{pmatrix} CNH \\ CNY_1 \\ CNY_2 \end{pmatrix}_{t-2} + L + A_p \begin{pmatrix} CNH \\ CNY_1 \\ CNY_2 \end{pmatrix}_{t-k} + \varepsilon_t \tag{1}$$

CNH_t is the return of offshore foreign exchange market, CNY1t is the return of cash selling rate/telegraphic transfer selling rate, k is the lag, ε_t is the white noise, T is the number of the samples.

In order to measure the overall risk contagion of the financial market, we build a simple GARCH-Granger overall risk contagion model, based on the return of financial markets. The conditional heteroscedasticity, which is the return volatility is calculated. Then, Granger causality test is used to determine the overall risk contagion and the direction. Firstly, we build GARCH (N,M) model, which is shown in Equation 3.

$$y_t^i = \mu^i + \sum_{k=1}^{K} a_k^i y_{t-k}^i + \varepsilon_t^i, \varepsilon_t^i \left| \varphi_{t-1}^i : \ N\left(0, h_t^i\right) \right. \tag{2}$$

$$h_t^i = \omega_t^i + \sum_{n=1}^{N} b_{t-n}^i \varepsilon_{t-n}^i + \sum_{m=1}^{M} c_{t-m}^i h_{t-m}^i \tag{3}$$

$y_t^i, \varepsilon_t^i, h_t^i$ are referred as the return series, the disturbing term and the conditional variance. $\mu^i, a_k^i, \omega_t^i, b_{t-n}^i, c_{t-m}^i$ are parameters to be estimated, K, N, M are lagging numbers. T=1,2,L,T.

Secondly, Granger test is applied between each two of the variables to determine the overall risk contagion and the contagion direction. The VAR model is shown in Equation 4.

$$\begin{pmatrix} h_t^i \\ h_t^j \end{pmatrix} = \begin{pmatrix} \varphi_{i0} \\ \varphi_{j0} \end{pmatrix} + \begin{pmatrix} \varphi_{ii}^{(1)} & \varphi_{ij}^{(1)} \\ \varphi_{ji}^{(1)} & \varphi_{jj}^{(1)} \end{pmatrix} \begin{pmatrix} h_{t-1}^i \\ h_{t-1}^j \end{pmatrix} + L + \begin{pmatrix} \varphi_{ii}^{(p)} & \varphi_{ij}^{(p)} \\ \varphi_{ji}^{(p)} & \varphi_{jj}^{(p)} \end{pmatrix} \begin{pmatrix} h_{t-p}^i \\ h_{t-p}^j \end{pmatrix} + \begin{pmatrix} \eta_t^i \\ \eta_t^j \end{pmatrix} \tag{4}$$

h_t^i, η_t^i are the return volatility and disturbing term in market i in the period t. $\varphi_{ij}^{(p)}$ is the estimated coefficient, p is the best lagging number in the VAR model, which is determined by AIC. The Granger causality test is followed to estimate the bidirectional causality.

Finally, the risk contagion parameter is set by analyzing the inter-market risk, and it is an effective improvement to analyze risk contagion. This is the guiding point for us to design the time-varying risk contagion model.

Referring Multivariate GARCH model, the time-varying risk contagion model is illustrated in Equation 5.

$$h_{ii,t} = c_{ii} + \beta\left(L\right) h_{ii,t} + \sum_{j=1}^{N} \gamma_j \left(L\right) h_{ji,t} + \alpha\left(L\right) \log\left(\varepsilon_{i,t}^2\right) \tag{5}$$

Since the risk contagion from Market j to Market i is mainly from the previous $h_{ji,t-g}$. Both of the markets have already got volatility $h_{ii,t-n}$ and $h_{jj,t-n}$. We introduce a random error term

$\eta_{ji,t}$, which obey the standard Gaussian distribution. The risk contagion model is constructed (Equation 6).

$$h_{ji,t} = c_{ji} + \gamma(L)h_{ji,t} + \beta_j(L)h_{jj,t} + \beta_i(L)h_{ii,t} + \sigma_{ji}^2\eta_{ji,t} \qquad (6)$$

$h_{ji,t}$ is a latent variable, and has real meaning. We can measure the market risk contagion from Market j to Market i, at time t. The final result is exponential transformed as $\exp(h_{ji,t})$.

4. Empirical Results: The Impulse Response of the Return Volatility in Offshore and Onshore Foreign Exchange Market

The VAR model is a basis for the variance decomposition and impulse response of the volatility variance of the offshore and onshore foreign exchange market. Some estimated results of the volatility of the offshore and onshore foreign exchange market VAR models are shown in Table 3, Table 4 and Table 5. IV is the abbreviation of independent variabiles while DV is the abbreviation of dependent variable.

Table 3

The Paramater Estimation of VAR for Stage 1

IV / DV	$CNH_t(-4)$	CNY_{1t} (-3)	CNY_{2t} (-2)	CNY_{2t} (-3)	c	R^2
CNH_t	0.0877	0.0283	0.5132	0.3691	-0.0004	0.1868
IV / DV	$CNH_t(-1)$	$CNY_{1t}(-1)$	CNY_{2t} (-2)	CNY_{2t} (-3)	c	R^2
CNY_{1t}	0.4082	-0.6977	0.7317	0.7777	-0.0004	0.4474
IV / DV	$CNH_t(-2)$	$CNY_{1t}(-2)$	$CNY_{2t}(-1)$	$CNY_{2t}(-4)$	c	R^2
CNY_{2t}	0.0610	0.0312	0.1388	-0.1312	-0.0005	0.0785

Table 4

The Paramater Estimation of VAR for Stage 2

IV / DV	$CNH_t(-1)$	$CNH_t(-2)$	CNY_{1t} (-1)	CNY_{2t} (-2)	c	R^2
CNH_t	-0.5665	-0.3890	0.1083	0.4905	-0.0003	0.2341
IV / DV	$CNH_t(-4)$	$CNY_{1t}(-1)$	CNY_{2t} (-1)	CNY_{2t} (-2)	c	R^2
CNY_{1t}	-0.1624	-0.2365	0.4447	0.1649	-0.0002	0.1526
IV / DV	$CNH_t(-4)$	$CNY_{1t}(-2)$	$CNY_{1t}(-4)$	$CNY_{2t}(-3)$	c	R^2
CNY_{2t}	-0.2206	0.1080	0.1067	0.1238	-0.0003	0.1189

Table 5

The Paramater Estimation of VAR for Stage 3

IV / DV	$CNH_t(-1)$	CNY_{1t} (-1)	CNY_{2t} (-2)	CNY_{1t} (-3)	c	R^2
CNHt	-0.3258	0.2678	0.2578	0.2002	-3.34E-05	0.0804
IV / DV	$CNH_t(-1)$	$CNH_t(-2)$	CNH_t (-3)	CNY_{1t} (-1)	c	R^2
CNY1t	0.1080	0.1662	0.1935	-0.1214	0.0000	0.0502
IV / DV	$CNH_t(-1)$	$CNY_{1t}(-1)$	$CNY_{1t}(-2)$	$CNY_{2t}(-2)$	c	R^2
CNY2t	-0.0683	0.1142	-0.0662	-0.0625	-0.0001	0.0326

Higher-order serial correlation on standardised residuals and squared standardised residuals is tested by Ljung-Box Q test (Table 6). There is no problem for serial correlation.

Table 6

The Ljung-Box Q test for the VAR Model

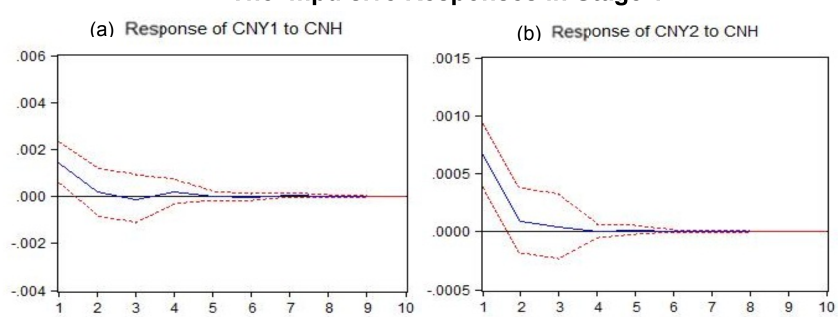
Time	8/25/2010-6/26/2011			6/27/2011-4/13/2012			4/14/2012-12/31/2014		
Index	*CNH*	*CNY*1	*CNY*2	*CNH*	*CNY*1	*CNY*2	*CNH*	*CNY*1	*CNY*2
Q(5)	0.7416	5.3840	0.4115	5.2757	2.5372	5.5015	1.2510	0.5011	0.7059
Q(15)	10.4510	13.4800	4.0511	9.5456	9.1644	9.6090	16.9450	21.4340	19.4310

Followed by the VAR model, the impulse response function is applied to analyze the return volatility between offshore and onshore foreign exchange market, the direction, extent and the duration. Due to the space constraints, we only list figures for the variables that have significant impulse response.

The impulsive effect for CNH, CNY1 and CNY2 in the first stage is illustrated in Figure 2. We can find that in the first stage, there is a significant positive impulse from CNH to CNY1 and CNY2 which lasts for more than four periods. Besides, the positive impulse of CNY2 to CNH lasted for five periods, which is also significant.

Figure 2

The Impulsive Responses in Stage 1

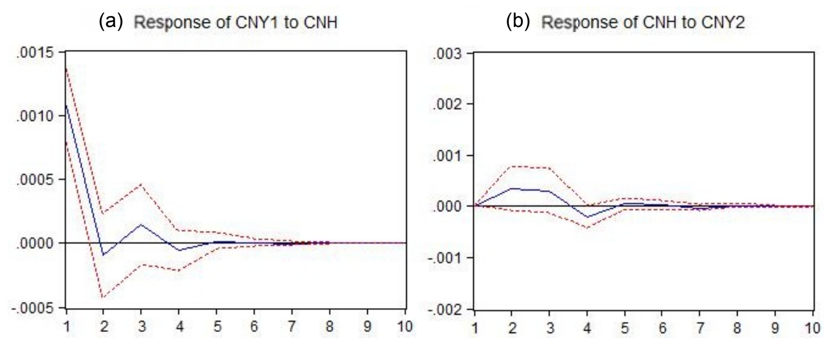


Source：Authors' calculation.

The impulsive effect for CNH, CNY1 and CNY2 in the second stage is illustrated in Figure 3. Except for the negative impacts in the second and fourth period, CNH has a significant positive impact on CNY1. On the other hand, CNH has a positive impact on CNY2 except for the third period. There is a positive impulsive impact from CNY1 to CNH for the first three periods. Starting from the fourth period, the impacts turn into negative. For CNY2, a positive impact in Period 1 and negative impact in Period 2.

Figure 3

The Impulsive Responses in Stage 2

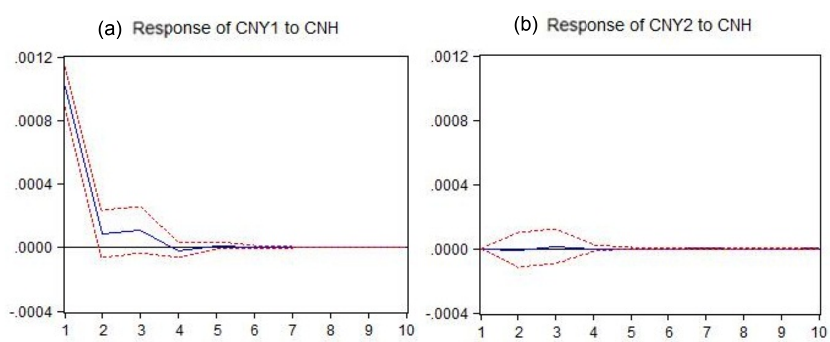


Source : Authors' calculation.

The impulsive effect for CNH, CNY1 and CNY2 in the third stage is illustrated in Figure 4. CNH has a significant positive effect on CNY1, lasting for more than three periods (a). However, its impact to CNY2 is weak (b). CNY1 and CNY2 have a positive impact on CNH, but the overall impact is weak.

Figure 4

The Impulsive Responses in Stage 3



Source : Authors' calculation.

Next, variance decomposition is used to further clarify the impulsive relation between the indices. In Stage 1, the variance decomposition result suggests that CNH has a significant impulsive effect to the return volatility of the onshore foreign exchange market. The CNH variance is slightly less than 8 in the CNY1 decomposition, while in CNY2 decomposition, CNH variance is 20 (Table 7). The impulsive effect of CNY2 to CNH is a little different compared with the result we get from the impulsive analysis.

Table 7

The Variance Decomposition of CNY1 and CNY2

Index	CNY1			CNY2		
Period	S.E.	CNH	CNY1	S.E.	CNH	CNY2
1	0.0045	10.1786	89.8214	0.0015	20.4608	79.5392
2	0.0052	7.8806	92.1194	0.0015	20.5308	79.4692
3	0.0052	7.9380	92.0620	0.0015	20.4972	79.5028
4	0.0052	7.8652	92.1348	0.0015	20.4926	79.5074
5	0.0053	7.7967	92.2033	0.0015	20.4900	79.5100
6	0.0053	7.8018	92.1982	0.0015	20.4898	79.5102
7	0.0053	7.7982	92.2018	0.0015	20.4898	79.5102
8	0.0053	7.7956	92.2044	0.0015	20.4898	79.5102
9	0.0053	7.7958	92.2042	0.0015	20.4898	79.5102
10	0.0053	7.7956	92.2044	0.0015	20.4898	79.5102

In Stage 2, the variance decomposition results suggest that CNY2 has a significant impulsive effect to CNH. The CNH variance is more than 20 in CNH decomposition. CNH has a significant effect on CNY1. In the decomposition, CNH variance is more than 40 in CNY1 decomposition. There can be some inconsistent for the variance decomposition and impulsive analysis, because the positive and negative effects can be generated in the same indices, causing offset to some extent (Table 8).

Table 8

The Variance Decomposition of CNH and CNY2

Index	CNH			CNY1		
Period	S.E.	CNH	CNY2	S.E.	CNH	CNY1
1	0.0021	75.5334	24.4666	0.0016	43.8581	56.1419
2	0.0022	78.6406	21.3594	0.0016	43.7349	56.2652
3	0.0023	77.1746	22.8254	0.0016	44.1343	55.8657
4	0.0023	77.2333	22.7667	0.0016	44.2016	55.7985
5	0.0023	77.3149	22.6851	0.0016	44.2063	55.7937
6	0.0023	77.2915	22.7085	0.0016	44.2064	55.7937
7	0.0023	77.2859	22.7141	0.0016	44.2065	55.7935
8	0.0023	77.2881	22.7119	0.0016	44.2065	55.7935
9	0.0023	77.2882	22.7118	0.0016	44.2065	55.7935
10	0.0023	77.2880	22.7120	0.0016	44.2065	55.7935

In Stage 3, CNH shows a huge impact on CNY1, and a rather weak impact on CNY2. The CNH variance is about 10 in the variance decomposition of CNY2. However, in the variance decomposition of CNY1, the CNH variance is more than 50. This shows a high consistent with the result of the impulsive effect analysis (Table 9).

Table 9

The Variance Decomposition of CNY1 and CNY2

Index	CNY1			CNY2		
Period	S.E.	CNH	CNY1	S.E.	CNH	CNY2
1	0.0014	53.6532	46.3468	0.0010	10.7717	89.2283
2	0.0014	53.7623	46.2377	0.0010	10.7994	89.2006
3	0.0014	54.0345	45.9655	0.0010	10.7424	89.2576
4	0.0014	54.0209	45.9791	0.0010	10.7420	89.2581
5	0.0014	54.0242	45.9758	0.0010	10.7418	89.2582
6	0.0014	54.0238	45.9763	0.0010	10.7418	89.2582
7	0.0014	54.0236	45.9764	0.0010	10.7418	89.2582
8	0.0014	54.0236	45.9764	0.0010	10.7418	89.2582
9	0.0014	54.0236	45.9764	0.0010	10.7418	89.2582
10	0.0014	54.0236	45.9764	0.0010	10.7418	89.2582

From the VAR analysis, we can generate a preliminary conclusion: the impulsive effect for the return volatility in offshore and onshore foreign exchange market varies through time. The magnitude and direction of the impact may vary. This finding indicates that it is more accurate to set different stages in the study.

5. Empirical Results: The Risk Contagion Analysis of Return Volatility between China's Offshore and Onshore Foreign Exchange Market

5.1 The Overall Contagion Analysis

The overall risk is calculated in two steps. Firstly, we use the generalized autoregressive conditional heteroscedasticity model to measure the return volatility in different markets. The results are illustrated in Table 10. The model fits well and there is no ARCH effect the residual. Q(5) and Q(15) are the statistics of the Ljung-Box test. Secondly, Granger causality test is applied to test the contagion relationship. The results are shown below (Table 11).

Table 10

The Parameter Estimation of CNH, CNY1 and CNY2 in the GARCH Model

Time	8/25/2010-6/26/2011			6/27/2011-4/13/2012			4/14/2012-12/31/2014		
Index	CNH	CNY1	CNY2	CNH	CNY1	CNY2	CNH	CNY1	CNY2
μ	-0.0002	-0.0003	-0.0004	-0.0003	-0.0002	-0.0002	-0.0001	-0.0001	-8.87E-05
ω	5.3E-07	-1.7E-07	2.2E-08	3.7E-06	1.1E-07	9.1E-08	3.9E-07	8.7E-08	1.1E-09
b	0.7073	1.0561	0.1030	0.2422	-0.0760	-0.0667	0.1820	0.1632	-0.0056
c	0.3382	0.6659	0.8729	-0.0452	1.0453	1.0309	0.7031	0.8063	1.0021
R2	0.0016	0.1037	0.0076	0.0903	0.0063	-0.0011	0.0079	-0.0050	-0.0031
Q(5)	6.1766	16.3911***	2.3489	2.8518	1.6684	5.2757	8.8431	5.3096	4.9444
Q(15)	14.5480	21.4920	5.5939	22.0450	9.8697	9.5456	30.6060**	38.1050***	19.0170

*Note:***、** respectively denote the original hypothesis was rejected at 1%, 5% significance level. Q(5), Q(15) are the statistics of the Ljung-Box test.*

Table 11
The Causality Test for the Risk Contagion between Offshore and Onshore Foreign Exchange Markets

Time	Null hyposisis	Lagging	F statistic	P value	Result
8/25/2010-6/26/2011	$CNH \rightarrow CNY\mathbf{1}$	2	4.2215	0.0306	Yes
	$CNY\mathbf{2} \rightarrow CNH$	2	1.9631	0.2917	No
	$CNH \rightarrow CNY\mathbf{2}$	3	8.3040	6.0E-5	Yes
	$CNY\mathbf{2} \rightarrow CNH$	3	1.2476	0.1459	No
6/27/2011-4/13/2012	$CNH \rightarrow CNY\mathbf{1}$	2	3.2077	0.0449	Yes
	$CNY\mathbf{1} \rightarrow CNH$	2	1.1706	0.3146	No
	$CNH \rightarrow CNY\mathbf{1}$	2	0.0326	0.9679	No
	$CNY\mathbf{2} \rightarrow CNH$	2	4.2389	0.0254	Yes
4/14/2012-12/31/2014	$CNH \rightarrow CNY\mathbf{1}$	3	3.5464	0.0148	Yes
	$CNY\mathbf{1} \rightarrow CNH$	3	1.0421	0.3740	No
	$CNH \rightarrow CNY\mathbf{2}$	2	0.3585	0.6990	No
	$CNY\mathbf{2} \rightarrow CNH$	2	0.4448	0.6413	No

In Stage 1, the offshore foreign exchange market has a significant risk contagion effect to the onshore market. The Granger causality test suggests risks in CNH is contagious to CNY1 and CNY2. However, CNH has a stronger contagion effect to CNY2 than to CNY1. In Stage 2, the contagion effect of CNH to CNY1 still exists, but its contagion effect to CNY2 has been weakened. In contrast, CNY2 has a contagion effect to CNH, showing an essential difference with Stage 1. In Stage 3, the return volatility risk of CNH remains a significant contagion effect on CNY1.

5.2 The Time-varying Contagion Analysis

Time-varying contagion model is applied to study the contagious effect of CNH to CNY1, and CNH to CNY2. This section is intended to see the contagion effect in the present caused by the fluctuations that has already taken place, and the fluctuations that are transmitted in the previous period. The least squares method is used, and the parameter estimation results are shown in Table 12. Higher-order serial correlation on standardised residuals and squared standardised residuals is tested by Ljung-Box Q test (Table 13).

There is a significant risk contagion effect between the offshore and onshore foreign exchange market, which verify the results of the overall contagion model to some extent. However, one most important feature of the time-varying model is revealing the existence of the risk and determining the approach.

In Stage 1, the volatility of CNH is risk contagious to the onshore foreign exchange market. All three coefficients are significant. But the contagious approaches are different. The risk contagion effect of CNH to CHY1 is achieved by the risk contagion approach (βji=0.2423). Meanwhile, the risk contagion effect of CNH to CNY2 is greatly influenced by the pre-contagion effect of the source market, the pre-contagion effect of the target market, and the risk contagion approach. The contagion parameter has reached to 0.3781, 0.2031 and 0.3561, suggesting that the risk contagion effect is more pronounced for the first and third indices.

In Stage 2, the volatility of CNH has a significant contagion effect on CNY1. The approach is pre-market volatility of the source market and the risk contagion approach (0.3140 and 0.3201, respectively). The volatility of CNY2 has contagion effect on CNH through the risk contagion approach as well, with risk contagion parameter of 0.2250.

In Stage 3, the risk contagion effect of CNH to CNY1 is mainly from the pre-volatility in the source market and the risk contagion parameter (coefficients are 0.4012 and 0.2050). The pre-volatility from the source market has a bigger contribution than the risk contagion parameter. We also find risk contagion effect between CNH and CNY2. The pre-fluctuation coefficients of the source market and the risk contagion rate were 0.2154 and 0.3304.

Table 12

The Parameter Estimation of Time-varying Model between Offshore and Onshore Foreign Exchange Market

Time	Index	c	Pre-fluctuation coefficient (the original market) α_{ii}	Pre-fluctuation coefficient (the influnced market) α_{jj}	Contagion rate β_{ji}
8/25/2010-6/26/2011	$CNH \rightarrow CNY1$	0.1208	0.1128	0.1285	0.2423
	$CNY1 \rightarrow CNH$	0.0648	0.0146	0.0538	0.0305
	$CNH \rightarrow CNY2$	0.2159	0.3781	0.2031	0.3561
	$CNY2 \rightarrow CNH$	0.0782	0.0535	0.0755	0.0348
6/27/2011-4/13/2012	$CNH \rightarrow CNY1$	0.1049	0.3140	0.1004	0.3201
	$CNY1 \rightarrow CNH$	0.0716	0.0484	0.1496	0.0105
	$CNH \rightarrow CNY2$	0.0632	0.0216	0.0413	0.1154
	$CNY2 \rightarrow CNH$	0.2943	0.1247	0.0158	0.2250
4/14/2012-12/31/2014	$CNH \rightarrow CNY1$	0.2016	0.4012	0.1472	0.2050
	$CNY1 \rightarrow CNH$	0.0649	0.0271	0.0948	0.1321
	$CNH \rightarrow CNY2$	0.1432	0.2151	0.1021	0.3304
	$CNY2 \rightarrow CNH$	0.0219	0.0122	0.1916	0.0917

Table 13

The Ljung-Box Q Test for the Time-varying Model

Time	8/25/2010-6/26/2011			6/27/2011-4/13/2012			4/14/2012-12/31/2014		
Index	CNH	CNY1	CNY2	CNH	CNY1	CNY2	CNH	CNY1	CNY2
Q(5)	6.6798	18.7841***	3.3369	11.2192**	2.5372	5.5015	13.3750**	5.6287	4.9296
Q(15)	16.4691	22.8732	12.3401	42.8102***	9.1644	9.6095	33.2362***	39.0057***	18.8643

****、** respectively denote the original hypothesis was rejected at 1%, 5% significance level. Q(5)、Q(15) are the statistics of the Ljung-Box test.*

Taken the time-varying risk contagion model as a whole, the offshore foreign exchange market has a significant risk contagion effect to the onshore foreign exchange market, although there is dynamic changes through time.

The differences in the risk transmission mainly due to the changes in the formation mechanism of RMB exchange rate in Hong Kong. When the Hong Kong CNH market initially formed (Stage 1), CNH exchange rate was the market price released by the Bank of Hong Kong. In Stage 2, Hong Kong Treasury Market Association launched the RMB exchange rate against US dollar as the benchmark price. In Stage 3, the People's Bank of China expanded the floating range of RMB from the daily 5 ‰ to 1%, making CNH market exchange rate more flexible. Changes in the mechanism of exchange rate formation have influnced the contagion risk.

The differences in the direction and the degree of infection are mainly due to the difference between the RMB telegraphic transfer selling rate and the central parity rate of RMB against US dollar. The latter is a weighted price set by China Foreign Exchange Trade Center, determined by the trading volume and quotations and other indicators of the inter-bank foreign exchange market. It is still intervened by the government monetary authorities to a certain degree, reflecting the policy guidance of the authorities. By contrast, the RMB telegraphic transfer selling rate is a market price referenced to the central parity rate of the RMB against US dollar. The difference between the two indicators may lead to very different results.

6. Conclusions

This paper made a thoroughly study for the risk contagion effect of return volatility between China's offshore and onshore foreign exchange market. The results have met our anticipation and consistent with previous studies to a certain degree (Wu and He 2014, Zhou and He 2015). The main conclusions are as follows.

Firstly, there is significant risk contagion effect between the offshore and onshore foreign exchange markets. Especially for the offshore to the onshore markets, the contagion effect is obvious.

Secondly, the direction and extent of the risk contagion effect between offshore and onshore foreign exchange market vary through time. In Stage 1, the volatility from CNH has a significant contagion effect to CNY1 and CNY2. In Stage 2, CNH still has influence to CNY1, but its contagion effect to CNY2 has been weakened. By contrast, CNY2 has a contagion effect to CNH, showing an essential difference with Stage 1. In Stage 3, CNH still has a significant contagion effect on CNY1.

Thirdly, the risk contagion effect between China's offshore and onshore foreign exchange market is mainly influenced by the risk contagion parameter of the source market. The pre-volatility in the source market and the volatility risk of the target market are both important to the risk contagion process. In Stage 1, the risk transition from CNH to CHY1 is achieved by the contagion parameter. All three indices contribute to the risk contagion effect for CNH to CNY2. In Stage 2, the volatility of CNH has a significant contagion effect on CNY1 through pre-market volatility of the source market and the risk contagion parameter. The volatility of CNY2 is risk contagious to CNH though the risk contagion parameter. In Stage 3, the risk contagion effect of CNH to CNY1 is from the pre-volatility in the source market and the risk contagion parameter.

As the offshore foreign exchange market has a significant impact on the return volatility of the onshore market, it is crucial to set the minimum-security standard in the offshore financial market supervision. For example, the ratio of working capital should be adjusted. Tax deduction and exemption should be applied to attract investors. Over-regulation undermines the market's own ability of risk management. As a result, moderate supervision is advised, and the regulation department need to be active in cultivating financial tools to manage the risk in the foreign exchange market.

International cooperation is essential in the procession of foreign exchange market business. Due to the different liquidity of foreign offshore banks and offshore joint venture banks, the standard varies. National regulatory authorities should strengthen cooperation and communication, preventing risks in the market.

In the end, we need to point out that there are some limitations for the study. It takes decades of effort for a currency to grow into an international currency. Therefore, some of the ideas in this paper cannot be tested in practice in the short run. Besides, since the offshore RMB financial market has just started, statistical support from the authoritative is lacked. The indices which can be selected in this paper are limited. In the future studies, more comprehensive statistical data can be used to study offshore RMB financial markets. We will get better results with the passage of time and the maturity of RMB offshore financial market.

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