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Exchange Rate Changes and Stock Returns in China: A Markov Switching SVAR Approach*

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Abstract

This study empirically investigates the spillover effects between exchange rate changes and stock returns in China. Evidenced by multivariate Granger causality tests, stock returns Granger-cause exchange rates changes, but exchange rate changes exhibit little effect on stock returns. As the conventional structural VAR (SVAR) approach fails to examine the contemporaneous effects, we apply the Markov switching SVAR model to allow the coefficients and variances of endogenous variables to be state-dependent. The regime-switching estimates indicate that the fluctuation in Shanghai B-share returns has positive effects on the remaining stock markets, but a negative impact on foreign exchange markets. This also reveals that the spillovers have longer durations during two financial crisis periods. Finally, this paper suggests investors to pay attention to systematic risks from RMB policy changes, which might alter the current unidirectional causality in the Chinese financial market.

JEL Codes: C32, C580, F31

Keywords: exchange rate changes, stock returns, Markov switching SVAR, Chinese financial market.

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1 Introduction

The classical economic theory pinpoints that there is a correlation between the currency market and the stock market performance. There are two schools of research in this sense. The first school is concerned about the current account balance (or trade balance) channel, which was proposed by Dornbusch and Fischer (1980). This approach has been dominant in the "flow-oriented" exchange rate models. The supporters of these models claim that the change in the exchange rate has an impact on international competitiveness and thereby affecting growth and real income. Stock prices respond to exchange rate changes since a firm's current value of future cash flows is expressed and interpreted by stock prices under efficiency of markets.[1] The second group is the "stock-oriented" exchange rate models (Frankel, 1983), which assume that innovations in stock markets influence aggregate demand through the wealth channel and liquidity effects, and therefore have an impact on the money demand (Gavin, 1989).

In the existing empirical literature, there has been a significant attention within academics and investors on the spillover effects between exchange rates and stock prices. In general, it is found that the dynamic relationship between stock prices and foreign exchange rates are either bidirectional (Granger et al., 2000; Pan et al., 2007; Rjoub, 2012), or unidirectional (Kim, 2003; Lin, 2012). Nonetheless, some studies find the non-existence of long run relationship between the two markets (Tabak, 2006; Ibrahim, 2000; Nieh and Yau, 2010). An interesting finding is that the spillover effects are found to be more apparent during financial crises (Granger et al., 2000; Fang, 2002).

The Chinese currency system is believed to protect the Chinese economy from external shocks to a greater extent, which also helps to stabilize the regional economy (Ma and McCauley, 2011). The international community is increasingly pressing the Chinese authorities to appreciate the RMB since it has caused large US trade deficits (Woo, 2008). In response to those pressures, China has to make appropriate changes to the currency policy. The RMB daily trading band has been widened from 0.3% (1994) to 0.5% (2007), 1% (2012), and 2% (2014).[2] These changes gradually make

[1]The fundamental theory of value suggests that the value for a financial asset at any point in time is equal to the present value of future cash flows. Empirical evidence can also be found on the study of Shanghai stock prices (Chow et al., 1999).
[2]See the RMB history via the link: www.thechinastory.org /lexicon/renminbi/.

the market play a big role in determining the RMB exchange rate. In conjunction with the “flow-oriented” and “stock-oriented” theories, the spillover effects between exchange rates and stock prices under the circumstance of an intermediate exchange rate policy in China is of interest to academics and also of importance to investors. Actually, there has been an increasing number of studies on the interactions between exchange rates and stock prices in China. The main findings of these studies reveal that foreign capital share returns in the Chinese stock market are not entirely segmented from global financial conditions (Bailey, 1994); there exists bidirectional volatility spillovers between stock prices and exchange rates (Zhao, 2010); asymmetric causal relationship running from exchange rates to A-share returns (Nieh and Yau, 2010). The disparities among these studies could be the application of different samples and econometric strategies. However, the Chinese stock market is constituted by RMB ordinary shares (known as A shares) and foreign capital shares (known as B shares). The evidence from both the A shares and B shares is commonly ignored in the previous literature. Moreover, the Hong Kong stock market is increasingly linked to the mainland stock market (Poon and Fung, 2000; Li et al., 2006; Johansson and Ljungwall, 2009). The investigation of the nexus between stock markets and foreign exchange markets in China should take all these indicators into account. Added to that, the gradual loosening of restrictions on the RMB exchange rate might have made the Chinese financial market more vulnerable than before, particularly during financial crises. Therefore, it would be of interest to look at spillover effects in different sample periods.

Different from previous studies on the Chinese financial market, this study investigates the causality between exchange rate changes and stock returns using a multivariate vector autoregression (VAR) approach. The test of causal relationships are based on the standard Wald tests. Since the VAR model is unrestricted and cannot examine structural innovations, we introduce the conventional structural VAR (SVAR) to explore the contemporaneous effects between exchange rate changes and stock returns. Nevertheless, the SVAR model is inadequate to interpret some of the shocks of interest due to the inherent weaknesses, such as the model identification techniques. Additionally, we apply the Markov switching SVAR model to investigate the spillover effects, with which both the mean and volatility spillovers could be examined. Besides, we use a high frequency data (daily data) in this study. The subsamples of financial crises are modelled separately, including the 1997 Asian financial crisis and the 2008 global financial crisis.

The remaining parts of this paper are organised as follows. The empirical literature on the interactions between exchange rates and stock prices is discussed in section 2. Section 3 presents econometric models and the technical inferences. Section 4 gives the data and preliminary statistics. Empirical results are shown in section 5 and the last section concludes.

2 Exchange Rates Changes and Stock Returns: the Empirical Literature

This section briefly reviews the literature on the relationship between exchange rates and stock prices according to the classification of different economies: emerging economies, developed economies and the interactions between emerging economies and developed economies.[3] China is widely considered to be an emerging economy due to its continuous growth since 1978, which has been receiving much attention from the international community.

With the fast growing of emerging economies and the increasing openness of the world economy, the dynamic linkages between exchange rate changes and stock returns in emerging markets have been subject of an increasing literature. Based on the Markov regime-switching framework, the empirical results show some discrepancies among different emerging markets: Chkili and Nguyen (2013) suggest that exchange rate changes have no effects on stock returns, but stock returns have a significant impact on exchange rate changes in BRICS countries except for South Africa; but Tovar-Silos and Shamim (2013) find a positive correlation between exchange rates and stock prices in South Africa; Walid et al. (2011) indicate that stock prices asymmetrically respond to currency movements in four emerging economies (Hong Kong, Singapore, Malaysia and Mexico), and exchange rate movements affect transition probabilities across regimes. It is noticeable that the number of literature on the correlation between exchange rates and stock prices in Asian emerging economies surged in the past two decades, due to their increasing influences in the Asia-Pacific region and their connections with the global economy, especially after

[3]This study classifies emerging economies referring to the classifications from the International Monetary Fund (IMF)(July 2012) and the Emerging Market Global Players (EMGP) project at the Columbia University (April 2013), as well as the list tracked by *The Economist*.

the 1997 Asian financial crisis (Fang, 2002; Granger et al., 2000; Lin, 2012).

Although stock markets in developed countries are assumed to have a sophisticated regime and may withstand the shock from currency movements, a number of studies find the existence of spillovers between exchange rates and stock prices, for example, Dominguez (2001) indicates that exchange rate movements have a significant impact on stock prices at both the firm and sectoral levels in industrial countries. For the US, (Bahmani-Oskooee and Sohrabian, 1992) find that the linkage between exchange rates and stock prices (S&P 500) is bidirectional in the short run. However, Kim (2003) and Choi et al. (1992) claim that the relationship between the two markets are unidirectional and negative, which runs from exchange rates to stock prices. As for G-7 countries, Nieh and Lee (2002) indicate that there is no long run relationship but the one-day correlation exists in the financial markets of Germany, Canada and UK.[4] Interestingly, Ma and Kao (1990) suggest that currency appreciations have a negative impact on the domestic market in an export-dominant economy since it weakens the competitiveness of export markets, while appreciated currencies reduce import costs and have positive effects on the domestic stock market if it is an import-dominated economy.

The existing literature suggests that spillover effects might spread from advanced financial markets to emerging markets (Coudert et al., 2011; Chow et al., 2011). The crisis happening in one emerging country may also spread to its neighboring emerging economies. Phylaktis and Ravazzolo (2005) point out that the positive correlations between exchange rates and stock prices in the Pacific Basin economies are linked through the channel of the US stock market, but the shocks from financial crisis to the long run interactions among these markets are temporal. Nevertheless, empirical evidence shows that currency shocks are not economically important for investors (Griffin and Stulz, 2001), since exchange rate shocks are exogenous to stock returns, which are mainly determined in the domestic market (Grammig et al., 2005).

[4]The one-day correlation means that the currency depreciation will drag down or stimulate stock returns on the following day.

3 Econometric Modelling

3.1 Theoretical Model and Conventional Structural VAR Model

The existing studies find that the correlation between exchange rate changes and stock returns is either bidirectional ($SR_t^j \Leftrightarrow ER_t^i$) (Pan et al., 2007; Rjoub, 2012), or unidirectional ($SR_t^j \Leftarrow ER_t^i$ or $SR_t^j \Rightarrow ER_t^i$) (Kim, 2003; Lin, 2012), or uncorrelated in the long run equilibrium (Tabak, 2006) and in the short run (Nieh and Yau, 2010), that is $SR_t^j \not\Leftrightarrow ER_t^i$. The conventional econometric method for examining the causal relationship between exchange rate movements and stock returns is the Granger causality test (Granger et al., 2000; Pan et al., 2007), which is based on the bivariate VAR (BVAR) model:

$$ER_t = \sum_{j=1}^{m} \alpha_j ER_{t-j} + \sum_{j=1}^{n} \beta_j SR_{t-j} + \varepsilon_t \tag{1}$$

$$SR_t = \sum_{j=1}^{m} \gamma_j ER_{t-j} + \sum_{j=1}^{n} \eta_j SR_{t-j} + \mu_t \tag{2}$$

Where ER_t and SR_t are exchange rate changes and stock returns, respectively. When β_j=0, stock returns fail to Grange-cause exchange rate changes. Exchange rate changes cannot Grange-cause stock returns only if γ_j=0. This study assumes that foreign capital shares and RMB ordinary shares in the Chinese stock market receive different spillover effects from foreign exchange markets, therefore the reduced form of the k -dimensional vector autoregressive (VAR) model with p-th lags is proposed (Lanne et al., 2010):

$$y_t = Dd_t + A_1 y_{t-1} + \cdots + A_p y_{t-p} + u_t \tag{3}$$

Where $y_t = (y_{1t}, \cdots, y_{nt})'$ is a $n \times 1$ dimensional vector. D is the coefficient matrix of the deterministic components d_t. A_i are $k \times k$ coefficient matrices for $i = 1, \cdots, p$, and u is a k-element vector of error terms. The causality test is based on the Wald tests of the lagged terms (shocks) in matrices A_i. However, the standard VAR approach for testing the causality is an unrestricted model, which cannot explore the contemporaneous effects between exchange rate changes and stock returns. Further stronger assumptions that are more directly associated with certain theories can be imposed on the structural VAR (SVAR) model (Mehrotra, 2007; Lanne et al., 2010). To specify the SVAR, we re-write equation (3) and incorporate additional contemporaneous endogenous shocks and the simple error structure into each equation. The typical A-B model form of the SVAR is expressed as:

$$Ay_t = D^s d_t + A_1^s y_{t-1} + ... + A_p^s y_{t-p} + B\varepsilon_t \tag{4}$$

Where y_t is a k-dimensional vector of endogenous variables. A (A is full rank), D^s, $A_i^s(i = 1 \sim p)$ and B are $k \times k$ structural form arguments matrices. ε_t is a k-dimensional identity covariance matrix vector of structural innovations. The matrix can be normalized as $\Sigma\varepsilon = I_k$. When $A = I_k$ and $B = I_k$, it is called as B-model and A-model, respectively. According to equation (3) and (4), $u_t = A^{-1}B\varepsilon_t$, and $\Sigma_u = A^{-1}BB'A^{-1\prime}$. Therefore, the model has $k(k+1)/2$ equations. Since both A and B have k^2 elements, thus a minimum of $2k^2 - \frac{1}{2}k(k+1)$ restrictions are required to identify matrices A and B. Estimating the SVAR is to minimise the log likelihood function:

$$lnL_c(A, B) = -\frac{KT}{2}ln(2\pi) + \frac{T}{2}ln|A|^2 - \frac{T}{2}ln|B|^2 - \frac{T}{2}tr(A'B'^{-1}B^{-1}A\tilde{\Sigma_u}) \tag{5}$$

Model overidentification can be examined applying the Likelihood Ratio (LR) test: $LR = T(logdet(\tilde{\Sigma_u^r}) - logdet(\tilde{\Sigma_u}))$. Where $\tilde{\sum_u}$ is the reduced form of the variance-covariance matrix and $\tilde{\sum_u^r}$ is the restricted structural form estimation. The SVAR model has to be identified by imposing restrictions based on theoretical assumptions. However, the statistical validity of these restrictions cannot be examined and the identification technique is usually inadequate to interpret some of the shocks of interest. Fortunately, the existence of various error covariance matrices across states in structural innovations can be captured by the Markov switching (MS) mechanism, which could also graphically present the distress and tranquil periods of an economy in the smoothed state probabilities.(Sims et al., 2008; Lanne et al., 2010).

3.2 SVAR Model with Different Volatility Regimes

In the MS-SVAR model, the distribution of the error term u_t is assumed to depend on a Markov process s_t (Lanne and Lütkepohl, 2010; Lanne et al., 2010; Netsunajev, 2013). Where s_t is a discrete state process with $t = (0, \pm 1, \pm 2, ... \pm M)$ and the transition probabilities are as follows:

$$p_{ij} = Pr(s_t = j | s_{t-1} = i), i, j = 1, ..., M. \qquad u_t | s_t \sim N(0, \Sigma_{s_t}) \tag{6}$$

Generally, the distribution of u_t conditional on s_t is assumed to be normal. This is just for the convenience of setting up the likelihood function. Pseudo maximum likelihood (ML) estimators is used when the conditional normality of $u_{t|s_t}$ does not hold. The covariance Σ_{s_t} in equation (6) varies across regimes and it is consistent with the statistical properties. The unconditional probabilities: $p(s_t = 0) = (1 - p_{11})/(2 - p_{11} - p_{22})$ and $p(s_t = 1) = 1 - p(s_t = 0)$. Concerning the switching states, the MS structure is a mix of normal disturbance terms. The structural shock identification for the MS model is based on the assumption that only the variances are orthogonal across states and it will not affect impulse response functions. In addition, temporary shocks will not change across all sample periods. Since the error term determines the structural shocks, any restrictions on the conventional SVAR inferred from theory models are testable and over-identified.

We can then rewrite the SVAR equation (4) as $A_0 y_{t-i} = F x_{t-i} + \varepsilon_t$, where y_{t-i} includes all the endogenous variables, F_i is coefficient matrices, x_{t-i} is a vector of lagged variables plus the constant term, and ε_t is a vector of unobserved random shocks. Sims et al. (2008) introduce the Markov switching SVAR in a Bayesian approach, but all matrices can be state-dependent:

$$A(s_t) y_{t-i} = F(s_t) x_{t-i} + \Xi^{-1}(s_t) \varepsilon_t \tag{7}$$

Where Ξ is a diagonal matrix of standard deviations ε_t and s_t is defined as m-states Markov process with transition matrix $Q = (q_{i,j})$ ($(q_{i,j})$ is the transition probability that $s_t = i$ given that $s_{t-1} = j$.). Equation (7) allows all the matrices to switch in a Markov process. The other two types of MS processes are the coefficients-switching and variances-switching, respectively.

The maximum likelihood (ML) estimation is commonly used in estimating the

MS-SVAR. The pseudo ML estimation is applied when the conditional normality distribution does not hold. The log likelihood function for a M-state MS-SVAR model: $logL_t = \sum_{t=1}^{T} logf(y_t|Y_{t-1})$, where $f(y_t|Y_{t-1} = \sum_{i=0}^{M} Pr(s_t = i|Y_{t-1})f(y_t|s_t = i, Y_{t-1})$. The (pseudo) conditional likelihood function is expressed as follows:

$$f(y_t|s_t = i, Y_{t-1}) = (2\pi)^{-k/2} det(\Sigma_i)^{-1/2} exp(\frac{1}{2} u_t' \Sigma_i^{-1} u_t), i = 1, ..., M. \tag{8}$$

Where Y_{t-1} is a matrix with the past information up to time t. $\Sigma_1 = BB', \Sigma_i = B\Lambda_i B', i = 1, ..., M$, u's are reduced form residuals (Lanne and Lütkepohl, 2010). The selection of state numbers really matters the Markov switching model. Considering the state changes in stock returns (or exchange rate changes), two or three states are normally selected,[5] but we have to test the validity of states selection in a statistical perspective.[6]

4 Data and Preliminary Statistics

Daily data were used in this study, spanning the period from 01/01/1994 to 31/12/2012. The daily exchange rates of USD against RMB (USD/RMB) and HKD against RMB (HKD/RMB) were collected from the State Administration of Foreign Exchange of China. Five market indexes were obtained from the Qianlong Securities trading software, namely the Shanghai A-share Index (SHAI), the Shanghai B-share Index (SHBI), the Shenzhen A-share Index (SZAI), the Shenzhen B-share Index (SZBI) and the Hang Seng Index (HSI). SHAI and SZAI are RMB ordinary shares, which are listed in the Shanghai and Shenzhen Stock Exchanges, respectively. SHBI and SZBI are foreign stock shares, which are traded in USD and HKD, respectively. The plots of exchange rates and stock indexes are shown in Figure 1.

Insert Figure 1 about here.

The commonly used method of calculating exchange rate changes is taking the natural logarithms of the division between two continuous closing values (Zhao, 2010; Walid et al., 2011). The changes in the exchange rate ER_t^i and stock returns SR_t^j in this study are calculated using the following equations:

[5] The structural innovations between stock returns and exchange rate movements can be positive, negative or no changes, so the number of states should be selected based on the information criteria.

[6] Normally, the log likelihood statistics with Akaike Information Criteria (AIC) and Schwarz Information Criteria (SIC) are reliable approaches to determine the best MS model.

$$ER_t^i = ln\left(\frac{p_t^i}{p_{t-1}^i}\right) \qquad SR_t^j = ln\left(\frac{q_t^j}{q_{t-1}^j}\right) \tag{9}$$

Where p_t^i denotes the exchange rate (USD/RMB or HKD/RMB) at time t. q_t^j is the stock index (j=1 to 5 for SHAI, SHBI, SZAI, SZBI, HSI, respectively) at time t. All variables (exchange rate changes and stock returns) are treated as endogenous variables in equations (3), (4) and (7). Table 1 reports summary statistics of exchange rate changes and stock returns. Since the VAR model requires that all variables need to be stationary, otherwise, we have to use the cointegration approach if there is a mix of integration orders. The stationarity of these series are examined by using the Augmented Dicky Fuller (ADF) unit root test (Dickey and Fuller, 1979) and the Phillips-Perron(PP) unit root test (Phillips and Perron, 1988). Table 2 reports the stationary test results. All of the statistics are significant at the 1% level, which implies that these variables are stationary in levels.

Insert Table 1 and 2 about here.

5 Empirical Results

5.1 Multivariate Granger Causality Test

Table 3 reports the multivariate Granger causality test results. In general, there are no spillover effects from RMB ordinary shares (SHAI and SZAI) to exchange rate changes. It can be expressed as $SR_A \nRightarrow ER$, where the subscript A denotes RMB ordinary shares. However, the shocks from the volatile returns of foreign capital shares on both the foreign exchange markets and stock markets are found to be statistically significant, especially the shock from Shanghai B-share returns, that is $SR_{SHBI} \Rightarrow ER$ and $SR_{SHBI} \Rightarrow SR$. Although the shock from the SZBI is not as large as that of the SHBI, the SZBI still has an important impact on the returns of the Shanghai stock market and the exchange rate of HKD/RMB, that is $SR_{SZBI} \Rightarrow SR_{Shanghai}$ and $SR_{SZBI} \Rightarrow ER_{HKD/RMB}$. After the 1997 Asian financial crisis and the return of Hong Kong, the Hong Kong stock market has close ties with the Shanghai stock market, the HSI has significant impact on the mainland foreign capital share returns, but it does not show any correlation with exchange rate changes. In addition, exchange rate changes exhibit no correlation with stock returns ($ER \nRightarrow SR$), but the effect from USD/RMB changes on HKD/RMB is found to be statistically significant ($ER_{USD/RMB} \Rightarrow ER_{HKD/RMB}$).

Insert Table 3 about here.

5.2 A Parsimonious Conventional SVAR Analysis

We estimate a SVAR model to observe the contemporaneous effects between exchange rate changes and stock returns. The most controversial part of the SVAR approach is the imposing of restrictions on the variance-covariance matrix. Following Sims (1986), this study derives the restrictions based on theory assumptions and practical experiences. According to equation (4) and its derivatives on the structural shocks, the restrictions on the SVAR are given in equation (10).

$$\begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} & a_{17} \\ a_{21} & 1 & 0 & a_{24} & a_{25} & a_{26} & 0 \\ 0 & 0 & 1 & 0 & a_{35} & a_{36} & 0 \\ a_{41} & 0 & a_{43} & 1 & 0 & a_{46} & a_{47} \\ 0 & 0 & 0 & a_{54} & 1 & a_{56} & 0 \\ 0 & a_{62} & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & a_{74} & 0 & a_{76} & 1 \end{bmatrix} \begin{bmatrix} u_t^{SHAI} \\ u_t^{SHBI} \\ u_t^{SZAI} \\ u_t^{SZBI} \\ u_t^{HSI} \\ u_t^{USD/RMB} \\ u_t^{HKD/RMB} \end{bmatrix} = \begin{bmatrix} \varepsilon_t^{SHAI} \\ \varepsilon_t^{SHBI} \\ \varepsilon_t^{SZAI} \\ \varepsilon_t^{SZBI} \\ \varepsilon_t^{HSI} \\ \varepsilon_t^{USD/RMB} \\ \varepsilon_t^{HKD/RMB} \end{bmatrix} \tag{10}$$

The first equation indicates that the SHAI responds to the shocks from other stock markets (SHBI, SZAI, SZBI and HSI) and foreign exchange markets (USD/RMB and HKD/RMB). Since the Shanghai stock market is more sensitive to external shocks, this study assumes that all variables have contemporaneous effects on the SHAI. The zero restrictions designate that there are no structural innovations from other markets. Similarly, the restrictions on other equations could be derived in the same manner. Lag length selection for the conventional SVAR model is determined by the information criterion. We use the same lag length as selected in the multivariate Granger causality test.[7] The restrictions on short run parameters might overidentify the SVAR model. In this case, the likelihood ratio (LR) test cannot completely reject the null hypothesis. The χ^2 statistic equals 4.7 with a p-value of 0.095, which partially accept the null hypothesis.[8] This implies that the short run

[7] Daily data are used in this study. The model estimates show that one lag is enough to white the error terms.

[8] The null hypothesis of this test is that any overidentifying restrictions are valid.

restrictions in equation (10) are just partly valid. Moreover, most impulse response functions (not reported) have a long duration with high parameter uncertainty in the estimated short run parameters. In conjunction with the overidentification test, the conventional SVAR estimates fail to interpret the contemporaneous effects between exchange rate changes and stock returns.

5.3 Empirical Analysis from SVAR with Markov Switching in Volatility

5.3.1 Model Selection and Prior Specifications

The state selection for MS models starts from 2 states, then we subsequently increase the number of states and change restrictions. Table 4 reports the log likelihood statistics and information criteria for MS models with different states and switching options. The unrestricted VAR and SVAR model do not present any indication of which model should be selected. While the MS-SVAR models have higher log likelihood statistics and lower information information criteria values. As shown in the table, panel A prefers the 3 states MS model with variances-switching. Panel B indicates that the 2 states MS model with coefficients-switching is the best model. Panel C demonstrates that 3 states with variance-switching is appropriate based on the subsample of the post-2008 global financial crisis.

Insert Table 4 about here.

The prior specifications for SVAR are the six hyper-parameters proposed by Sims and Zha (2006).[9] In the Markov switching process, each element of the diagonal matrix $\xi^2(s_t)$ is a gamma distribution prior and the parameters (α, β) are set as $\bar{\alpha} = 1$ and $\bar{\beta} = 1$ in Gamma(α, β) (Sims et al., 2008). The prior on the transition matrix Q is a Dirichlet distribution, which have unrestricted parameters $\alpha_{i,j}$ and restricted parameters β_{ij}. In the transition matrix Q, all the off-diagonal elements are set as one and the diagonal elements are computed by $\alpha_{jj} = \frac{p_{j,dur(h-1)}}{1-p_{j,dur}}$, where $p_{j,dur}$ is the average duration of the Markov chain.

[9]Following Sims and Zha (2006), the prior specifications in this study are $\mu_1 = 0.57, \mu_2 = 0.13, \mu_3 = 0.1, \mu_4 = 1.2, \mu_5 = 10$ and $\mu_6 = 10$.

5.3.2 Volatility Structure and Impulse Response Analysis

In the MS-SVAR model, the volatility structure is demonstrated in the Markov chain with transition probabilities. The transition probabilities among states are reported in Table 5. It is clear that each state has a high probability in maintaining its ongoing state, which is indicated by the diagonal elements of each matrix. The probabilities of state transition between state 1 and state 2 are very low. It is possible that the low volatility (state 2) can move to state 3, and vice versa, but the state transition between the high volatility (state 1) and the transition state (state 3) will never occur in this case.

Insert Table 5 about here.

Insert Figure 2 about here.

Figures 2-4 represent smoothed state probabilities for three different samples. Each MS-SVAR model has different switching states, which are referred to as distressed state, normal (tranquil) state and transition state.[10] Figure 2 depicts separate states for panel A, which allow us to have a clear view on the dynamic structure of the Chinese financial market. The whole sample estimates integrate the Markov process of the state-dependent variances, which are full of volatilities across the sample period. The high volatility (state 1) is associated with the bull or bear market. Since the middle of 2006, the Chinese stock market experienced a dramatic increase. The market index (Shanghai A-share index) surged above 6100 (the historical peak) in November 2007, increased by 280% compared with the price index in July 2006 (1600). During the 2008 world financial crisis, the Chinese stock market suffered severe shocks and the market index declined below 2000 by the end of 2008. A vast number of investors made a great fortune overnight during 2006 and 2007, but most private and institutional investors went bankrupt during the crisis. The tranquil and transition period are captured by state 2 and state 3, respectively. Since daily data is used in the study, the MS model fully captures the volatilities in the Chinese financial market, but it is quite hard to give a clear interpretation for each single state across the sample period. Therefore, we reestimate the MS model using post-crisis subsamples.

Insert Figures 3-4 about here.

[10]The economic activity and financial turbulence usually have two categories: the normal regime and the distressed regime (Davig and Hakkio, 2010), but some cases may have more than two regimes, so the stepwise regime name can be given, for example, the transition regime (between the normal regime and the distressed regime).

Figure 3 depicts smoothed state probabilities for the subsample over the period 1 July 1997 to 31 December 2007. Distress states can be demonstrated by the high volatility in mid-1997 and late 2007. State 1 gives the high volatility from mid-1997 to mid-1999 and the turmoil in the late 2007, although several tranquil periods appeared during that time. State 2 captures several tranquil periods and the relative long-lasting stable state starts from mid-2001 to mid-2006. Figure 4 represents smoothed state probabilities since the onset of the 2008 world financial crisis. High volatility in state 1 indicates the distressed time in 2008, mid-2010 and around second quarter of 2011. State 2 captures the normal state from late 2008 to mid-2010. State 3 is the transition state, capturing several transition periods from mid-2010 to early 2011, and from mid-2011 to late 2012. This means that the market entered the consolidation phrase.

The impulse response functions for the three samples are given in Figures 5-7. These shocks with parameter uncertainty capture spillover effects between stock markets and foreign exchange markets. For panel A (Figure 5), the SHAI shock has positive effects on the SZAI and itself, but negative influences on the SHBI and USD/RMB. Nonetheless, the shocks on the SZBI, HSI and HKD/RMB are difficult to ascertain since the impulse response function with confidence intervals cross the zero line. The SHAI shock is relatively short (2 days) and the USD shock is comparatively long-lasting (6 days). Other shocks commonly have a duration of 4 periods. Concerning the sign of these shocks, the SHBI shock has positive effects on other stock markets but negative effects for exchange rate changes. The SZAI is negatively correlated with SHAI, SHBI and HKD/RMB, but it exhibits positive effects on the returns of Shenzhen stock indexes. In the Shenzhen stock market, the SZBI shock has negative effects for foreign capital shares but its influences on other markets are still ambiguous. The USD/RMB shock has positive effects on foreign exchange markets, which is also more likely to be positively correlated with RMB ordinary shares but negatively related to foreign capital shares. The positive USD/RMB shock indicates the depreciation of the local currency, which leads to a boost of RMB ordinary shares. No clear conclusions could be given to other shocks since the impulse responses cross the zero line with high parameter uncertainty (indicated by the dash line).

Insert Figure 5-7 about here.

The impulse response graphs from the two subsamples exhibit different structural innovations. The duration of the shocks in panel B (Figure 6) is about 10 days, while the shocks last about 6 days in the sample of the post-2008 global crisis (Figure 7). Both are longer than the shocks represented in panel A. It is apparent that the duration of structural innovations on stock markets from foreign exchange markets are two periods longer than those on foreign exchange markets themselves. This means that exchange rate changes have significant contemporaneous effects on stock returns, although there are no long run spillovers on stock returns. In addition to the duration of shocks, the subsample investigations also reveal that the SHBI shock has positive effects on stock markets but a negative impact on foreign exchange markets.

In general, we find that exchange rate changes cannot Granger-cause stock returns, but foreign capital share returns, specially the SHBI, exhibit significant impact on the remaining stock market returns and exchange rate changes. Although Shenzhen B shares are traded in HKD, the fluctuation in SZBI returns has spillover effects on Shanghai stock markets, which are also correlated with the HKD/RMB. In spite of the fact that the Hong Kong market is increasingly linked to the mainland stock market, we find that HSI returns do not show significant impacts on RMB ordinary share returns but demonstrate apparent correlations with the SHBI. Furthermore, the MS-SVAR estimates capture the dynamic structure of the Chinese financial market since 1994. The smoothed state probabilities graphically depict the distressed and normal periods of the Chinese financial market. In conjunction with the multivariate Granger causality test, the results from impulse response functions are consistent with the identified causal relationships. The Shanghai B-share returns have positive effects on stock returns of other markets but negative effects for exchange rate changes. In accordance with previous studies, the estimates from two subsamples suggest that the shocks during financial crises have longer durations. This implies that the interaction between exchange rates and stock prices is strengthened during financial crises.

Looking inside the realities of the Chinese financial market, any shocks from the foreign exchange market could be limited in the short run, since the managed floating exchange rate system has restrictions on the RMB daily trading band. Even the shock continues, investors might have adjusted to the adverse shock. Thus, exchange rate changes exhibit no correlation with stock returns. However, with the relaxing of restrictions on the RMB, the shock from currency movements appears to be significant as demonstrated by subsample estimates. Looking to the future, the authorities are trying to internationalise the RMB, this might bring systematic risks to the Chinese financial market and alter the current unidirectional relationship between exchange rate changes and stock returns.

6 Concluding Remarks

This study has explored the correlation between exchange rate changes and stock returns in the Chinese financial market. The multivariate Granger causality test suggests that only a unidirectional relationship exists running from stock markets to foreign exchange markets. The returns of RMB ordinary shares do not have any impact on exchange rate changes ($SR_A \nRightarrow ER$), but the Shanghai B-share returns have significant spillover effects on the remaining stock markets and foreign exchange markets ($SR_{SHBI} \Rightarrow ER$ and $SR_{SHBI} \Rightarrow SR$). After the return of Hong Kong, the Hong Kong stock market has close ties with the mainland stock market. HSI returns exhibit significant influences on foreign capital shares but show no correlation with RMB ordinary share returns and exchange rate changes. This is due to the linked exchange rate system in Hong Kong. Since the conventional SVAR model estimates fail to test the spillover effects, we then introduce the MS-SVAR approach to investigate the spillovers between exchange rate changes and stock returns, which is able to capture the volatile structure of the Chinese financial market. In line with the identified causalities, the MS-SVAR estimates reconfirm that the SHBI shock has positive effects for other stock markets but a negative impact on exchange rate changes. In accordance with the existing literature, subsample analysis in this study indicate that the spillover effects between exchange rate changes and stock returns during financial crises have longer durations.

As for practical implications, investors could make appropriate adjustments referring to the fluctuations of the SHBI. The shocks from the Hong Kong stock market are also potential risks to their investment returns since the linkages between the Hong Kong stock market and the mainland stock market are ever increasing. Although exchange rate movements only exhibit contemporaneous spillovers on stock returns, investors need to pay attention to the RMB policy changes, since the daily RMB trading band is gradually loosening and the speed of the RMB internationalisation is accelerating. This could bring systematic risks to the Chinese financial market and change the current unidirectional causalities.

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Table 1: Summary statistics of exchange rates and stock indexes

Panel A: Descriptive statistics for exchange rate changes						
	Mean	Std.Dev	Skewness	Kurtosis	Normality	Q(36)
USD/RMB	0.0000	0.0006	-8.3541	262.1573	11130***	142.56***
HKD/RMB	0.0000	0.0007	-2.2688	78.7551	31398***	103.81***
Panel B: Descriptive statistics for stock returns						
SHAI	0.0002	0.0204	1.4403	27.428	10461***	114.61***
SHBI	0.0001	0.0213	0.1361	5.2011	2073.3***	127.62***
SZAI	0.0003	0.0209	0.6177	14.768	6984.2***	80.906***
SZBI	0.0002	0.0215	0.0756	6.3514	2749.8***	78.501***
HSI	0.0001	0.0170	0.0672	9.2621	4485.4***	65.134***

Notes:

1. Exchange rate changes and stock returns were calculated according to equation (9).
2. *** denotes the rejection of the null hypothesis at the 1% level.
3. The normality test is based on the study of ?. They argue that the JB test (Jarque and Bera, 1987) has poor small sample properties and the skewness and kurtosis are not independently distributed, also the speed of sample kurtosis closes to normality very slow. The test statistic as: $e_2 = z_1^2 + z_2^2 \sim \chi^2(2)$.
4. Q(36) is the 36th order of Ljung-Box Q-statistics in levels.

Table 2: Stationary tests of exchange rate changes and stock returns

	USD/RMB	HKD/RMB	SHAI	SHBI	SZAI	SZBI	HSI
ADF	-66.905(0)	-74.047(0)	-28.802(5)	-62.148(5)	-68.201(0)	-64.365(0)	-69.892(0)
PP	-68.351(22)	-74.109(21)	-70.611(10)	-63.058(19)	-68.393(8)	-65.129(17)	69.920(12)

Notes:

1. The restrictions for the ADF and PP tests in levels are the constant without trend.
2. Both the critical values for the ADF and PP tests are -3.43 at 1% level, and all the test results reject the null hypothesis at 1% level.
3. The number in parenthesis is the lag length, which is selected by the Schwarz information criteria (SIC) and the Bartlett kernel bandwidth for the ADF and PP tests, respectively.

Table 3: Multivariate granger causality test

	SHAI	SHBI	SZAI	SZBI	HSI	USD/RMB	HKD/RMB
Panel A: Test from the whole sample (1 January 1994 to 31 December 2012)							
SHAI		1558.71(0.000)	12.25(0.001)	16.79(0.000)	0.23(0.634)	0.31(0.580)	1.30(0.255)
SHBI	0.60(0.439)		3.02(0.082)	4.97(0.026)	3.86(0.049)	1.07(0.300)	0.05(0.827)
SZAI	9.14(0.003)	1737.37(0.000)		17.22(0.000)	0.00(0.945)	0.25(0.620)	0.41(0.521)
SZBI	4.08(0.433)	4329.36(0.000)	2.52(0.113)		1.63(0.201)	0.30(0.586)	0.07(0.785)
HSI	0.24(0.626)	408.44(0.000)	1.09(0.296)	11.12(0.001)		0.04(0.842)	0.55(0.459)
USD/RMB	0.49(0.485)	9.60(0.002)	0.00(0.954)	2.95(0.086)	12.32(0.000)		3.86(0.050)
HKD/RMB	0.15(0.670)	7.84(0.005)	0.01(0.929)	3.81(0.051)	1.70(0.193)	280.37(0.00)	
Panel B: Test from the subsample (1 July 1997 to 31 December 2007)							
SHAI		1213.11(0.000)	0.76(0.382)	23.84(0.000)	3.45(0.063)	1.73(0.189)	0.45(0.504)
SHBI	4.33(0.038)		1.74(0.187)	2.32(0.128)	7.20(0.007)	2.08(0.149)	0.24(0.626)
SZAI	2.13(0.144)	1128.46(0.000)		16.70(0.000)	0.08(0.774)	0.68(0.409)	0.17(0.684)
SZBI	3.94(0.047)	2925.89(0.000)	2.39(0.122)		2.42(0.120)	0.71(0.400)	0.33(0.567)
HSI	2.39(0.122)	119.79(0.000)	0.28(0.594)	0.38(0.539)		0.21(0.649)	2.79(0.095)
USD/RMB	0.03(0.866)	9.38(0.002)	0.29(0.587)	1.68(0.195)	1.87(0.172)		0.53(0.466)
HKD/RMB	0.16(0.690)	6.66(0.010)	0.18(0.668)	2.76(0.097)	0.10(0.752)	387.84(0.000)	
Panel C: Test from the subsample (1 January 2008 to 31 December 2012)							
SHAI		1213.11(0.000)	0.76(0.382)	23.84(0.000)	3.45(0.063)	1.73(0.189)	0.45(0.505)
SHBI	4.33(0.038)		1.74(0.018)	2.32(0.128)	7.20(0.007)	2.08(0.149)	0.24(0.626)
SZAI	2.13(0.144)	1128.46(0.000)		16.70(0.000)	0.08(0.774)	0.68(0.409)	0.17(0.684)
SZBI	3.94(0.047)	2925.89(0.000)	2.39(0.122)		2.42(0.120)	0.71(0.400)	0.33(0.567)
HSI	2.39(0.122)	119.79(0.000)	0.28(0.594)	0.38(0.539)		0.21(0.649)	2.79(0.095)
USD/RMB	0.03(0.866)	9.38(0.002)	0.29(0.587)	1.68(0.195)	1.87(0.172)		0.53(0.466)
HKD/RMB	0.16(0.690)	6.66(0.010)	0.18(0.668)	2.76(0.097)	0.10(0.752)	387.84(0.000)	

Notes:

1. The Granger causality test is to test the coefficient of lagged parameters applying the Wald test.
2. Numbers in parentheses are P-values.

Table 4: MS models selection

Model	logL_T	AIC	SIC
Panel A: Information criteria for the whole sample			
VAR unrestricted	125846.2	-51.406	-51.332
SVAR	125872	*NA*	*NA*
2 states, all-change	124054.395	-50.658	-50.599
2 states, switching coefficients	133712.513	-54.600	-54.533
2 states, switching variances	133712.513	-54.600	-54.533
3 states, all-change	124054.695	-50.58	-50.599
3 states, switching coefficients	136894.876	-55.893	-55.801
3 states, switching variances	**137273.818**	**-56.031**	**-55.883**
Panel B: Information criteria for the subperiod(01/07/1997-31/12/2007)			
2 states, all-changes	71018.512	-52.438	-52.342
2 states, switching coefficients	**78247.333**	**-57.773**	**-57.662**
2 states, switching variances	78262.776	-57.769	-57.612
3 states, unrestricted	71222.758	-52.581	-52.461
3 states, switching coefficients	72283.871	-53.354	-53.204
3 states, switching variances	72283.871	-53.323	-53.081
Panel C: Information criteria for the subperiod(01/01/2008-31/12/2012)			
2 states, all-change	33632.550	-52.523	-52.346
2 states, switching coefficients	34794.682	-54.330	-54.124
2 states, switching variances	34547.171	-53.910	-53.619
3 states, all-change	33717.623	-52.639	-52.417
3 states, switching coefficients	34795.523	NA	NA
3 states, switching variances	**35066.098**	**-54.660**	**-54.213**

Notes:

1. *NA* indicates that the MS model cannot converge based on such restrictions.
2. The bold texts indicate the best MS model for each panel.

Table 5: Transition probabilities among states

MS model	Transition probabilities
Panel A: the whole sample period	
3 states, switching variances	$\begin{bmatrix} 0.8690 & 0.0768 & 0 \\ 0.1310 & 0.8463 & 0.1828 \\ 0 & 0.0768 & 0.8172 \end{bmatrix}$
Panel B: 01/07/1997-31/12/2007	
2 states, switching coefficients	$\begin{bmatrix} 0.8699 & 0.0521 \\ 0.1301 & 0.9479 \end{bmatrix}$
Panel C: 01/01/2008-31/12/2012	
3 states, switching variances	$\begin{bmatrix} 0.9115 & 0.0503 & 0 \\ 0.0885 & 0.8993 & 0.0346 \\ 0 & 0.0503 & 0.9654 \end{bmatrix}$

Figure 1: **Exchange rates and stock indexes**

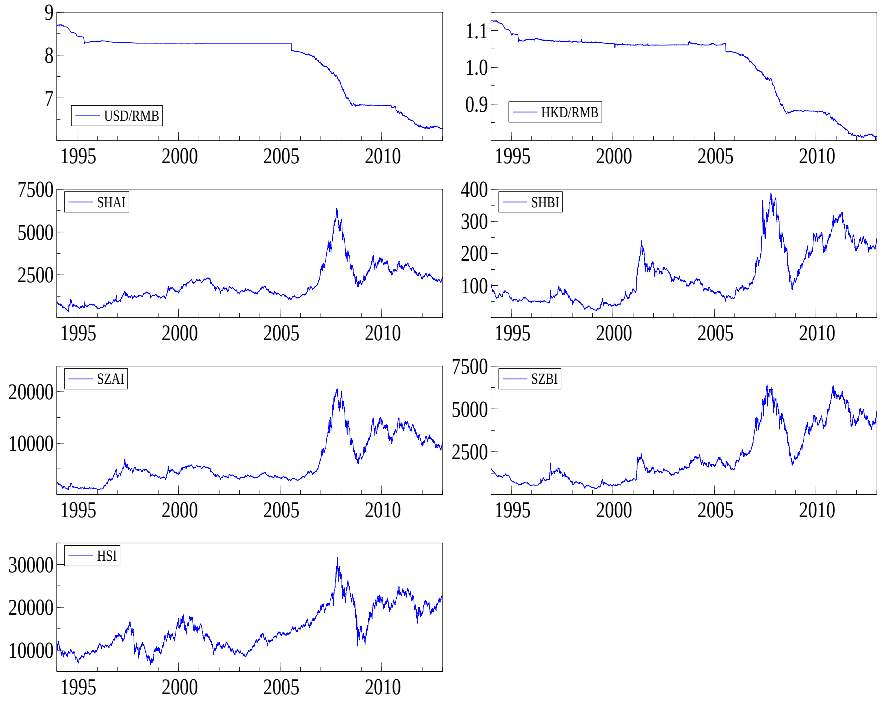

Figure 2: **Smoothed state probabilities for panel A**

(01/01/1994-31/12/2012)

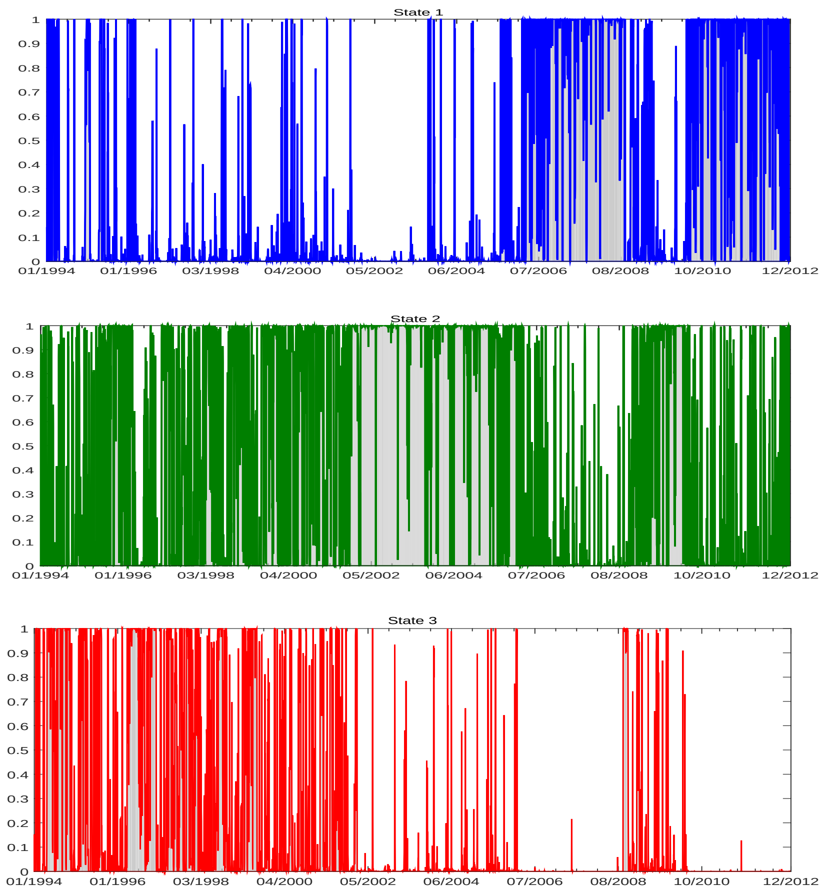

Figure 3: **Smoothed state probabilities for panel B**

(01/07/1997-31/12/2007)

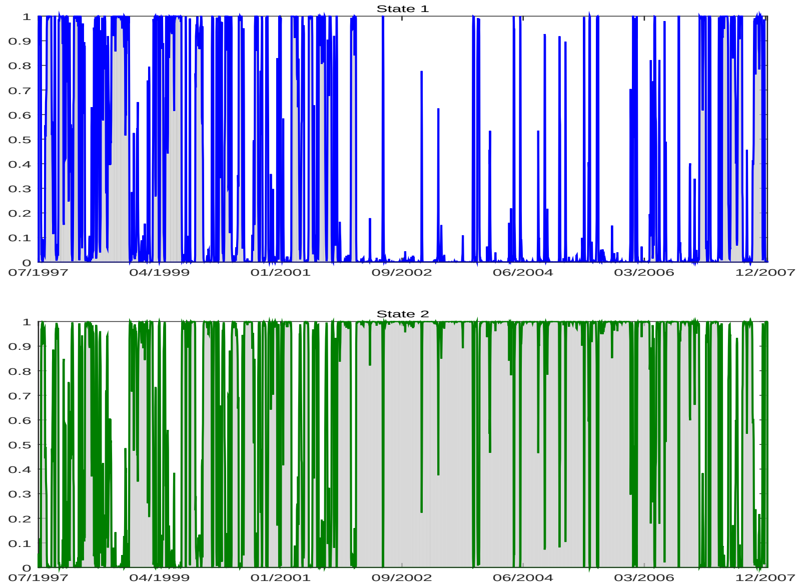

Figure 4: **Smoothed state probabilities for panel C**

(01/01/2008-31/12/2012)

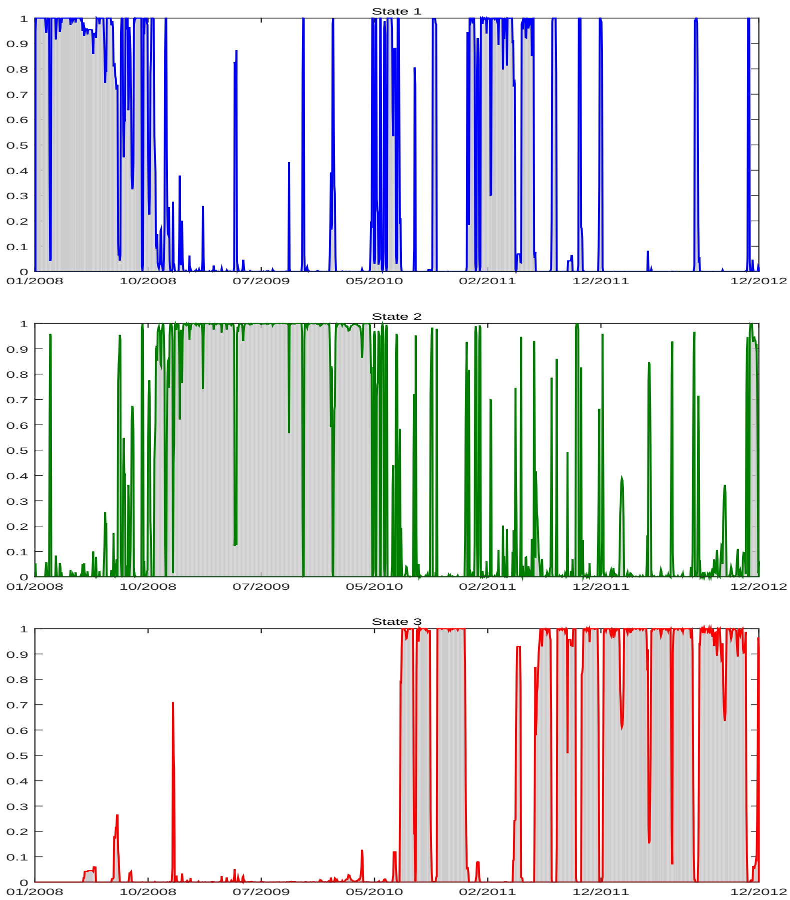

Figure 5: Impulse response functions for panel A

(Sample period:01/01/1994-31/12/2012)

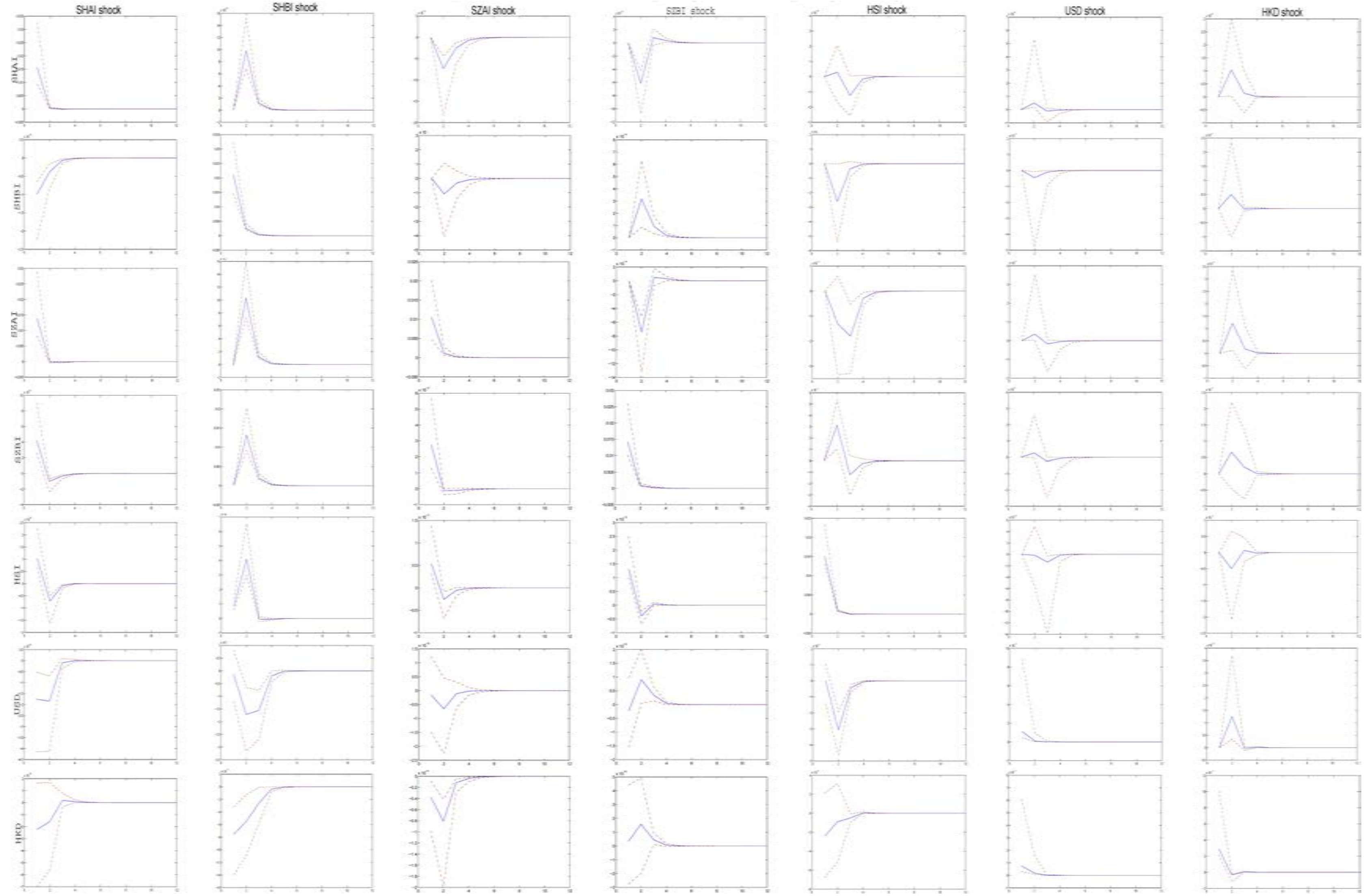

Figure 6: Impulse response functions for panel B

(Sample period:01/07/1997-31/12/2007)

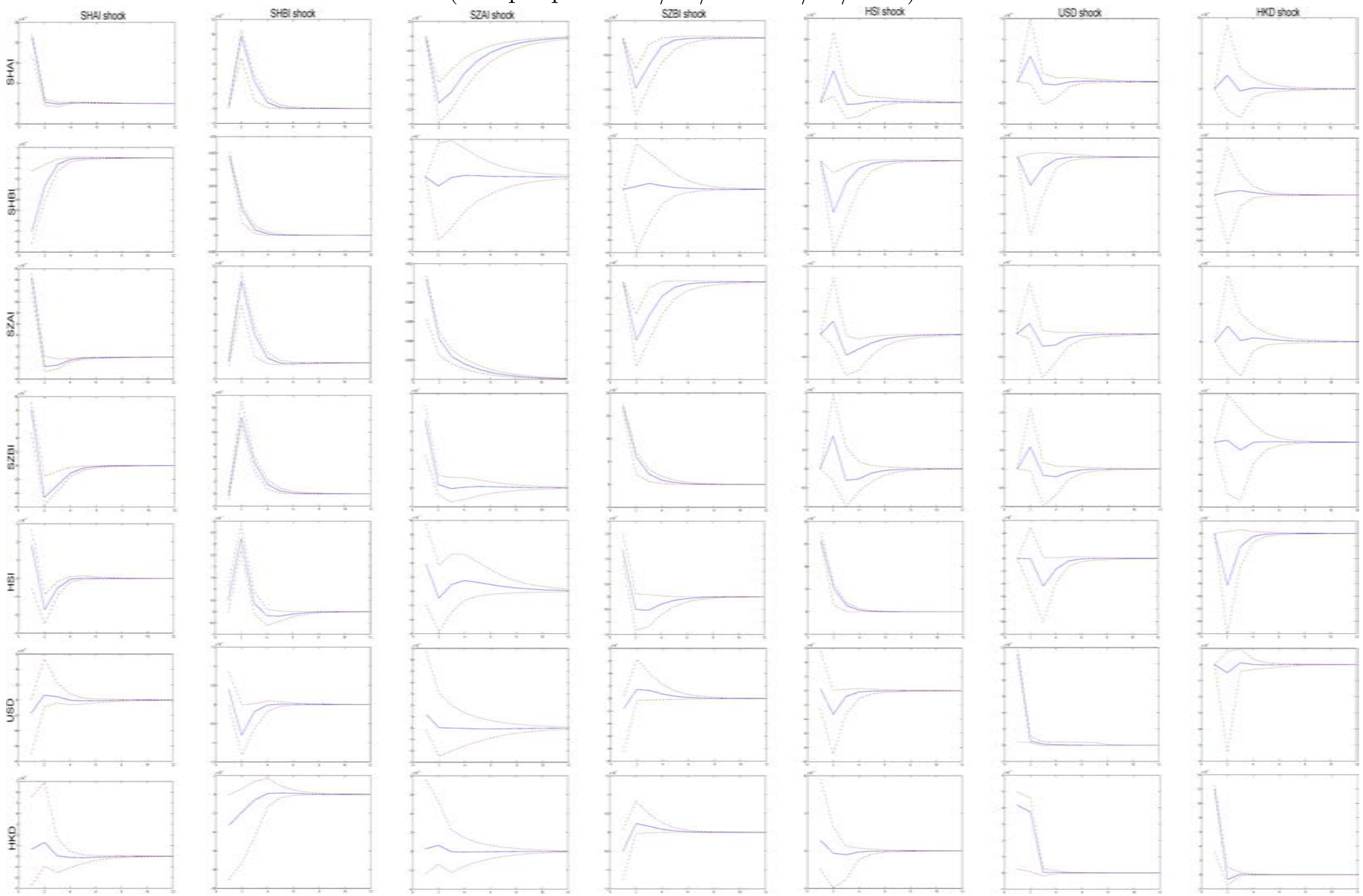

Figure 7: Impulse response functions for panel C

(Sample period:01/01/2008-31/12/2012)