Exchange Rate Dynamics and Risks in China: Empirical Evidence

Bo Tang

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To Those Who Love and Take Care of Me

Abstract

In spite of a voluminous literature on the Chinese economy and its currency policy, the dynamics and risks of the Renminbi (RMB) exchange rate remain unsatisfactorily answered. To address these issues, this thesis builds upon the existing literature to investigate exchange rate dynamics and exposure in China. Generally, the thesis consists of three separate yet related empirical chapters that aim to unlock the secret of China's growth and uncertainties in the Chinese financial market, which have received much attention from policy-makers, academics and investors. Empirical evidences from four different levels are presented in this thesis. At the country level, it examines the linkage between the exchange rate and economic growth and confirms that the Chinese economy is driven by the expansion of exports but exhibits little correlation with the RMB exchange rate. At the market level, spillover effects emerge from stock returns to exchange rate changes, but exchange rate changes have less impact on stock prices in the long run due to the restriction on the daily trading band of the RMB. At the industry level, significant exchange rate exposure is identified, in particular for manufacturing industries. At the firm level, exchange rate exposure presents significant size effects, which indicate that large firms relatively suffer more during the ups and downs of the exchange rate than small firms. This is explained by the expansion of global operations for large firms. Specifically, the three chapters, in the order which they appear, are summarised as follows:

First, the long run equilibrium and short run dynamics between the real exchange rate (RER) and economic growth in China are examined in Chapter 2. The empirical findings from cointegration tests suggest that the Chinese economy has not benefited from the lower RMB exchange rate, and the RER is not correlated with China's growth in the long run. As the two cointegrating relationships reveal, the Chinese economy is stimulated by the expansion of exports and inflow of foreign capital, which also indicate that the RMB equilibrium exchange rate is jointly determined by foreign trade, foreign reserves and foreign direct investment. Moreover, the 2005 RMB policy reform did not show any significant impact on the RER, but instead contributed to the steady economic growth. Added to that, after the 2008 world financial crisis, the RMB exchange rate is largely relied on the increase in GDP and inflow of foreign capital, rather than the slow increase in foreign trade. As for policy implications, China may insist on the managed floating exchange rate policy making limited adjustments to the currency's daily floating range in response to the pressure from trade partners.

Second, spillover effects between exchange rate changes and stock returns in the

Chinese financial market are investigated in Chapter 3. As the multivariate Granger causality test demonstrates, only a unidirectional relationship exists running from stock returns to exchange rate changes. To examine contemporaneous shocks between the stock market and the foreign exchange market, the conventional structural VAR (SVAR) is applied in the chapter, but the model estimates fail to explain some of the shocks of interest. Nevertheless, the Markov switching SVAR model allows the coefficients and variances to be state-dependent, which is able to capture the dynamic structures of the Chinese economy. The regime-switching model estimates suggest that Shanghai B-share returns have positive effects on the remaining stock markets but a negative impact on foreign exchange markets, which also show that spillover effects have longer durations during two post-crisis periods. Although exchange rate changes cannot Granger-cause stock returns in the long run, the contemporaneous spillovers on stock returns are found to be statistically significant. In the end, this chapter suggests that investors should pay attention to systematic risks from RMB policy changes, which may alter the current unidirectional causality in the Chinese financial market.

Finally, Chapter 4 examines the exchange rate exposure of Chinese firms at both the industry and firm level building upon the conventional capital asset pricing model (CAPM) framework. At the industry level, the dynamic conditional correlation MGARCH (DCC MGARCH) model estimates demonstrate that the market model and three-factor model are appropriate for exposure measurements, and industry returns are more likely to be exposed to unanticipated changes in the real exchange rate and the trade-weighted effective exchange rate, particularly for manufacturing industries. At the firm level, although the seemingly unrelated regression (SUR) estimates vary across markets, it is apparent that there is a relationship between firm size and exposure effects, which also show that lagged exchange rate changes have significant exposure effects on firm returns. This chapter eventually suggests that non-financial firms should set up special commissions to hedge currency risks of their future cash flows.

JEL classification: C32, C58, E44, F31, F43, G12, G32, O24

Keywords: Real exchange rate, economic growth, cointegration, vector error correction model, spillover effects, exchange rate changes, stock returns, Chinese financial markets, Markov switching SVAR, capital asset pricing model, exchange rate exposure, industry level, firm level, dynamic conditional correlation MGARCH, seemingly unrelated regression

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List of Abbreviations

ADF	Augmented Dickey-Fuller
ARDL	Autoregressive distributed lag
ASEAN	Association of Southeast Asian Nations
BIS	Bank for International Settlements
BRICS	Brazil, Russia, India, China and South Africa
CAPM	Capital Asset Pricing Model
CPI	Consumer price index
CSRC	China Securities Regulatory Commission
CUSUM	Cumulative sum of residuals
CVAR	Cointegrated vector autoregressive
DCC MGARCH	Dynamic conditional correlation multivariate GARCH
DGP	Data generating process
EG	Engle Granger
FDI	Foreign direct investment
FER	Foreign exchange reserves
GARCH	Autoregressive conditional heteroskedasticity
GLS	Generalized least squares
HKD	Hong Kong Dollar
HSI	Hang Seng Index
IMF	International Monetary Fund
JB	Jarque-Bera
KPSS	Kwiatkowski-Phillips-Schmidt-Shin
MS SVAR	Markov switching structural VAR
NER	Nominal exchange rate
PBOC	People's Bank of China
PP	Phillips-Perron
RER	Real exchange rate
RGDP	Real gross domestic product
RMB	Renminbi
SHAI	Shanghai A-share index
SHBI	Shanghai B-share index
SHCOMP	Shanghai Stock Exchange Composite
SICOMP	Shenzhen Stock Exchange Component Index
SSE	Shanghai Stock Exchange
SUR	Seemingly Unrelated Regression
SVAR	Structural VAR
SZAI	Shenzhen A-share index
SZBI	Shenzhen B-share index
SZSE	Shenzhen Stock Exchange
TWEER	Trade-weighted effective exchange rate
VAR	Vector autoregressive
VaR	Value at Risk
VECM	Vector error correction model

Chapter 1

Introduction

1.1 Motivation

The rapid growth of the Chinese economy and the continuous depreciation of the Chinese currency (Renminbi, RMB) have attracted significant attention from investors, policy-makers and academics for decades. Investors would like to seek out information about investment opportunities and potential risks in the Chinese market. Policy-makers (or trade partners) continuously press the Chinese authorities to appreciate the RMB in order to reverse their unfavorable trade situations. While academic researchers aim to unlock the secret of China's growth relating to the managed floating exchange rate policy. Since the unification of the market and official exchange rates accompanied by a substantial reduction in currency controls in 1994, the currency trading band was gradually widened to 2% in 2014, letting the market power plays a big role in determining the RMB exchange rate.[1] Regarding the Chinese economy and its currency, what is the genuine relationship between the RMB exchange rate and economic growth? Do exchange rate changes have spillover effects on the Chinese financial market? With the rapid expansion of exports, are Chinese firms subject to exchange rate changes at the industry and firm level? These are fundamental questions associated with the RMB exchange rate and the Chinese economy. Although some of these questions have been partially explored in the existing literature, their findings still cannot address the concerns of many researchers, for instance, the potential relationship between real exchange rate and growth, spillover effects between exchange rate changes and stock returns in the Chinese financial market, and the possible risk of Chinese exporting firms. Empirical studies on exchange rate dynamics and risks are mainly focused on advanced economies with floating exchange rate regimes. Therefore, the research on the dynamics and risks of a managed floating exchange rate system has important theoretical and practical significance, particularly in China.

Empirical studies have found that economic growth is positively correlated with

[1] See the RMB history studied by the "The Australian Centre on China in the World" via the link: www.thechinastory.org/lexicon/renminbi/.

floating exchange rate systems but negatively related to fixed currency regimes (Sokolov et al., 2011). Although intermediate currency regimes have less flexibilities, Tu (2012) finds that there is a positive relationship between the intermediate currency policy and economic growth in emerging economies. Flexible exchange rates are subject to market uncertainties and external shocks, which may have significant influences on the domestic economy. The depreciation and appreciation of these currencies might have spillover effects on regional economies or other major trade partners. Nevertheless, this study considers the dynamics and risks of the RMB exchange rate under the managed floating exchange rate system,[2] which has historically been criticised by trade partners as they believe that the depreciated Chinese currency has put them at a disadvantage. It is still a puzzle whether this kind of exchange rate system has benefited growth or not, however, the Chinese authorities have to respond to the pressure from trade partners and adjust the currency policy. Although the daily floating range of the RMB exchange rate is restricted, this study conjectures that the Chinese economy might be correlated with the fluctuation of the RMB exchange rate (e.g., foreign reserves, foreign trade, foreign capital inflows), and spillover effects exist between the Chinese stock market and the foreign exchange market. The change in the exchange rate might further put Chinese exporting firms at risk.

1.2 What Does this Study Investigate?

The main aims of this study are to explore exchange rate dynamics and risks in China based on empirical evidence. Specifically, this thesis investigates the long run equilibrium and short run dynamics between real exchange rate (RER) and economic growth, the spillover effects between exchange rate changes and stock returns, and the exchange rate exposure of Chinese firms at the industry and firm level. In doing this, three separate but related chapters are organised in the following manner: (1) several macroeconomic indicators are incorporated into the equation of RER determinants, including foreign reserves, imports, exports and foreign investments, to explore the relationship between RER and economic growth using a cointegrated vector autoregressive (CVAR) approach (in Chapter 2); (2) spillover effects between

[2]The Chinese currency policy experienced dramatic changes since 1978. In July 2005, the authorities implemented the managed floating exchange rate policy. However, it is still found to peg to the US dollar (Frankel and Wei, 2007).

exchange rate changes and stock returns are examined (in Chapter 3) using a Markov switching structural VAR (MS-SVAR) model, which captures the volatile structure in the Chinese financial market; and (3) the exchange rate exposure of Chinese firms are investigated (in Chapter 4) at the industry and firm level employing macroeconometric and microeconometric methods, respectively, which reflect the exposure of firm returns at both macro and micro levels.

The first empirical chapter (Chapter 2) of this thesis aims at the examination of the dynamic relationships between RER and growth in China, which mainly addresses the speculation and puzzles faced by trade partners that China's growth is bound up with its low exchange rate. To carry out the investigation, this chapter combines the long run equilibrium between RER and its determinants (the RER equation) (Edwards, 1988; Edwards and Savastano, 1999; Miao and Berg, 2010; Abida, 2011), and the growth models (Aguirre and Calderón, 2005; Harms and Kretschmann, 2009; Tarawalie, 2011; Gluzmann et al., 2012), to construct the theoretical framework. In order to revisit structural changes of the currency policy reform in 2005, a dummy variable is included in the model. As we are not sure about the potential cointegration relationship between RER and the growth indicators, the CVAR approach is introduced. The structural break is examined both inside and outside of the vector error correction model to ensure the robustness of the test results. Considering possible changes to the long run correlation between RER and growth due to external shocks, the subsample of the post-2008 global financial crisis is reestimated, which allows us to observe the subtle change to the RER-growth relation after the great recession.

The linkages between stock markets and exchange rate markets have been the research focus of empirical finance for decades. Given that the Chinese financial market might receive less external shocks due to the protection mechanism of the currency system, spillover effects between the Chinese stock market and foreign exchange markets may exist but might have been restricted. To test this hypothesis, both RMB ordinary shares and foreign capital shares, as well as the Hang Seng Index, are included in the sample, which are immensely important for observing the cross-market spillovers. Since the shocks during financial crises periods are commonly tested in previous studies, therefore the subsamples of the 1997 Asian financial crisis and the 2008 financial crisis are explored separately. The causality between exchange rate changes and stock returns is examined in the multivariate

VAR model, but the unrestricted VAR could not observe structural innovations. In order to address this issue, the structural VAR (SVAR) model with restrictions on the long run and short run parameters are applied. However, the normality assumption on the residuals of the SVAR model usually does not hold, and also the short run and long run restrictions are really counterintuitive. Finally, the Markov switching SVAR (MS-SVAR) method allows the coefficients and variances of the conventional SVAR to be state-dependent, which could be an appropriate approach for modelling spillovers.

To our knowledge, the existing literature has documented evidence that multinational firms are exposed to unanticipated changes in exchange rates (Adler and Dumas, 1984; Jorion, 1990; Dominguez and Tesar, 2001; Muller and Verschoor, 2006). Since the managed floating exchange rate system only has restrictions on the daily floating range, this study assumes that Chinese exporting firms are still subject to potential risks from the change in the exchange rate. The exposure analysis is carried out building upon the conventional capital asset pricing model (CAPM) framework. To carry out the investigation, both industry level and firm level data are collected. The industry level exposure is examined applying the dynamic conditional correlation MGARCH (DCC MGARCH) model, which models the dynamic structure of industry returns to the change in the exchange rate. While the firm level exposure analysis is carried out using the Seemingly Unrelated Regression (SUR) approach, which models the exposure discrepancies among different size of exporting firms. Considering the nature of exchange rate exposure in China, lagged exchange rate changes are included in the model, which are expected to capture lagged exposure effects on firm values due to the restriction on the RMB daily floating range. Since 2005, the RMB exchange rate started to refer to a basket of currencies, but it is mainly pegged to the USD (Frankel and Wei, 2007). Thus, the bilateral exchange rate of USD to RMB is considered in the chapter. In order to test the exposure caused by different types of exchange rates, nominal exchange rate, RER and trade-weighted effective exchange rate are obtained for the exposure analysis.

1.3 Contribution of this Study

This thesis contributes to the literature on RMB exchange rate dynamics and risks on several grounds. The study empirically examines the long run and short run correlation between RER and growth in China, the dynamic spillover effects between exchange rate changes and stock returns in the Chinese financial market, and the exchange rate exposure of Chinese firms at the industry and firm level. The systematic analysis on exchange rate dynamics and risks in China in such an in-depth empirical research has not been explored previously in the literature. The primary contributions of this thesis are as follows.

First, Chapter 2 investigates the long run equilibrium and short run dynamics between RER and growth in China. It not only provides new insights into how the RMB exchange rate is affected by Chinese macroeconomic indicators, but also unlocks the secret of China's growth. Despite of the implementation of a managed floating exchange rate regime, this study finds that the Chinese economy has not benefited from the lower RMB exchange rate, and no direct relationship could be found between RER and growth in the long run. This finding helps to address the puzzle of trade partners that the depreciation of the RMB exchange rate stimulates China's growth. The Chinese economy is promoted by the accelerated expansion of exports and inflow of foreign capital. This might give an implication to trade partners that they need to seek strategic foreign trade policies when they trade with China, rather than putting more efforts in pressing the Chinese authorities to appreciate the RMB, since the Chinese currency is gradually participating in the global financial market and the yuan's exchange rate has to be adjusted to adapt to the equilibrium pursuant to the multilateral trade situations. Different from the existing RMB real effective exchange rate studies, the evidence in this chapter demonstrates that the Chinese currency is jointly determined by foreign trade, foreign reserves and foreign direct investment.

Although many researchers believe that the 2005 RMB policy reform had significant changes to the Chinese economy, the revisit of the effect of the currency policy change confirms the non-existence of structural breaks, which is consistent with previous studies (Shah et al., 2005; Zhiwen, 2011). The policy change did not affect the stability of the Chinese currency but impacted on economic growth. After the 2008 world financial crisis, the RMB exchange rate is less dependent on the slow increase in exports, but relies upon the rise of its national strength and inflow of foreign capital. This implies that the Chinese currency is adjusting itself to adapt to the global financial market, and no single factor could play a major role on the RMB exchange rate. Finally, the policy contribution of Chapter 2 for the Chinese authorities is the adjustment of the RMB exchange rate. The Chinese government could insist on the ongoing managed floating exchange rate policy making limited adjustments to the daily floating range to respond to the pressure from trade partners.

Second, the investigation of spillover effects in the Chinese financial market in Chapter 3 is helpful for policy-makers and investors to understand the interaction between foreign exchange markets and stock markets under the circumstance of continuing restriction on the currency's daily floating range. Apparently, the chapter contributes to the literature on a wide range of spillover effects in the Chinese financial market, including RMB ordinary shares, foreign capital shares and the Hang Seng Index. This has not been explored previously in the existing literature. This chapter also contributes to the studies on modelling spillover effects with high-frequency (daily) datasets, whereas monthly and quarterly datasets are commonly used in existing studies. With regard to research methods, this chapter sequentially introduces the multivariate VAR, the SVAR and the MS-SVAR to model the causality and structural innovations in the Chinese financial market. These methods provide new insight into the investigation of the causal relationship and spillovers between exchange rate changes and stock returns.

The findings on the causality between exchange rate changes and stock returns in this study are also useful for investors, since it recognises the unidirectional causality in the Chinese financial market. When there is a shock happening in the foreign exchange market, investors do not need to quickly respond to the shock as exchange rate changes cannot Granger-cause stock returns. Although the SVAR model fails in the identification of structural innovations, the MS-SVAR model with regime-switching captures the dynamic spillover effects, which indicates that the Shanghai B-share returns have positive effects on the remaining stock markets but a negative impact on foreign exchange markets. This could be used as a barometer for investors since the fluctuation of the Shanghai B-share index might affect the returns of other markets. The findings of the MS-SVAR modelling also depict the tranquil and tough periods of the Chinese financial market, which is quite helpful for people to understand the historical trend (the bull and bear markets). Furthermore, the subsample analysis of this chapter contributes to the literature on the investigation of spillovers during financial crises, which show that the spillovers have longer durations during these periods.

Finally, the exchange rate exposure analysis of Chinese exporting firms in Chapter 4 has important theoretical and practical implications. It contributes to the literature on exchange rate risks of Chinese firms at both the industry and firm levels. Specifically, the industry level exposure analysis demonstrates that industry returns are exposed to different types of exchange rate changes.[3] It is of importance to investors to gain insight into exposure disparities across industries. Manufacturing industries are more likely to be exposed to changes in the exchange rate as most exporting firms are manufacturing companies. This implies that investors need to pay more attention to the fluctuation in the exchange rate when they invest in manufacturing industries. The finding of a correlation between firm size and exposure effects at the firm level suggests that large firms suffer more exposures, since they usually have more overseas operations than small firms. Being consistent with the existing literature, this chapter also finds lagged exchange rate exposure effects at both the industry and firm level. This is supported by the ongoing managed floating exchange rate policy in China, which temporarily restricts the shock from exchange rate fluctuations. Moreover, this chapter contributes to the literature on the investigation of exchange rate exposure at both the industry and firm levels, particularly in the research method. This study applies a macroeconometric approach and a microeconometric approach to model the industry and firm level exposures, respectively, which has not been explored previously in the literature. Last but not least, the exposure analysis on the changes in the nominal exchange rate, RER and trade-weighted effective exchange rate (TWEER) is helpful for policy makers and investors to understand exposure discrepancies among different types of exchange rate changes. It might also be of importance to those researchers who are interested in the weights for a basket of currencies which the RMB is referring to, since this chapter finds that Chinese firms suffer more exposure effects from the change in the TWEER.

[3]The market level evidence in Chapter 3 shows that exchange rate changes cannot Grange-cause stock returns in the long run, whereas the industry and firm level estimates reveal that exchange rate changes have significant influences on firm and industry returns. This is due to the application of different datasets and methodologies. The managed floating exchange rate policy may protect Chinese firms against external shocks at the market level, but the industry and firm level exposures still exist, since different industries have different degrees of involving in global operations, and large firms usually have more overseas operations than small firms.

1.4 Structure of this Thesis

This thesis consists of five chapters. Chapter 2 explores the long run equilibrium and short run dynamics between RER and economic growth applying the CVAR approach. The structural change of the 2005 RMB policy reform is re-examined, as it is widely argued in the existing literature. This chapter finally analyses the RER-growth relationship after the onset of the 2008 global financial crisis. Subsequently, Chapter 3 investigates spillover effects between exchange rate changes and stock returns in the Chinese financial market, using the MS-SVAR approach, which allows the model coefficients and variances to be state-dependent. The subsample of the 1997 Asian financial crisis and 2008 global financial crisis are modelled separately in the chapter. Chapter 4 then examines the exchange rate exposure of Chinese firms at both the industry and firm level. On the one hand, based on the capital market approach, the industry level exposure is estimated using the DCC MGARCH model. On the other hand, based on the cash flow approach, the firm level exposure is estimated applying the SUR model. Lastly, Chapter 5 presents an overall summary of the thesis, proposes possible policy implications of these findings, and gives some interesting topics for future studies.

Chapter 2

Real Exchange Rate and Economic Growth in China: A Cointegrated VAR Approach

2.1 Introduction

With an average annual growth rate of 9.1% from 1989 to 2014,[4] the rise of China and its currency system have received much attention from policymakers and researchers all around the world (Tyers et al., 2008; Soleymani and Chua, 2013). It is believed that the lower RMB exchange rate has promoted growth in China but has harmed trade partners' economies. Actually, the Renminbi (RMB) has appreciated by almost 38% since 1994, but it still cannot meet trade partners' expectations. The international community has been criticizing the slower speed of RMB appreciation (Morrison and Labonte, 2011). The US authorities are even increasingly pushing China to change its currency policy since the RMB was overvalued against the US dollar (USD) by 40% according to the US congressional bill in 2007 (Woo, 2008). It seems that the RMB exchange rate has played a vital part in boosting the Chinese economy, therefore, trade partners are increasingly pressing Chinese authorities to appreciate currency and make the RMB more flexible and tradable in the foreign exchange market (Zhang, 2013; McKinnon and Schnabl, 2014). Taking the above into consideration, the main aims of this chapter are to explore the dynamic linkages between the RMB real exchange rate and economic growth both in the long run and short run, to investigate the structural change in the currency policy reform which took place in 2005, and to look at the effects on the RMB exchange rate after the 2008 global financial crisis.

Previous studies have found that the fluctuation of real exchange rate (RER) has a vital impact on economic growth (Tarawalie, 2011; Benhima, 2012; De Vita and Kyaw, 2011). The general definition of the RER is adjusting the NER with foreign and domestic price levels.[5] From trade partner's perspective, China's growth has benefited from the lower RMB exchange rate and its managed floating exchange

[4] Source: National Bureau of Statistics of China.

[5] Generally, the RER is defined as the NER adjusting for foreign ($P_t^\star$) and domestic (P_t) price levels, that is $RER_t = NER_t \frac{P_t^\star}{P_t}$.

rate policy.[6] To reverse the bilateral trade situation, they are increasingly putting pressures on the Chinese authorities to appreciate the RMB, although it suffers from continual appreciation in the past two decades (see Figure 2.1).[7] Historically, the RMB exchange rate regime reform could be divided into three periods.[8] The first period was the pre-reform period which started from the founding of new China in 1949 to the implementation of opening door policy in 1978. The Chinese authorities encouraged exports and maintained the long term stability of foreign exchange receipts and expenses to keep the RMB strong. The remarkable characteristics of the RMB exchange rate at this stage was the long-held policy of pegging the currency to the USD. The second stage reform lasted from 1978 to 1994. There was a sharp depreciation in the Chinese currency during that period since the government adopted a fixed exchange rate and only pegged the currency to the USD. The RMB had a dual exchange rate regime and policymakers mainly focused on the accumulation of foreign incomes. For foreign trade policies, the authorities encouraged exports and limited imports. The third stage was also the reform stage (1994 to 2010). Free competition was encouraged in this stage. Since January 1994, the RMB official rate began to practice the managed floating exchange rate regime based on the demand and supply in the market. In Figure 2.1, the exchange rate of USD to RMB always maintained at the level of 8.3 until the policy reform in 2005. In July 2005, China implemented a managed floating exchange rate policy based on market supply and demand, referring to a basket of currencies, then the RMB gave up the long-time policy of pegging to the USD. The single pegged exchange rate regime gradually changed into managed floating exchange rate regime, and finally appeared to be more flexible after 2010. However, the US authorities still believe that the Chinese currency is undervalued according to the US congressional research service report.[9] They criticize the slower pace of RMB appreciation since China has a continuous growth and increasing exports, which might have benefited from its currency system.

To maintain a stable RMB exchange rate, China has a higher storage of foreign

[6] Over the last few years, the international community claims that China is manipulating the international currency and trade systems in its own favour.

[7] The exchange rate used in this chapter is the RMB central parity rate which was collected from the People's Bank of China (PBOC). The PBC announces the closing prices of different foreign currencies trading with RMB among banks after the closing transaction of each working day, which will be the next day's central parity rate of the foreign currency against RMB.

[8] Li-Gang Liu (2010). China's Exchange Rate Policy: Evolution, Latest Developments, and Future Directions. Italian Central Bank.

[9] See Morrison and Labonte(2010). China's Currency: An Analysis of the Economic Issues, congressional research services.

exchange reserves (FER). It is believed that abundant FER can withstand the shock from cross-border capital flows to a greater extent. According to the International Monetary Fund (IMF) guidelines for foreign reserves management,[10] FER are held to support and maintain confidence in monetary and exchange rate policy (Olokoyo et al., 2009). Figure 2.2 represents that the FER in China had an exponential increase, particularly since 2005, it dramatically speeded up to $3,311.598 billion by the end of 2012. The growth speed slowed down and even maintained a minus increase since the fourth quarter of 2011 according to a recent report published by the State Administration of Foreign Exchange.[11] The decline of the FER suffered from the slowdown of RMB appreciation and the increase in people's willingness of selling foreign currencies.

Continuous and stable growth is the striking feature of the Chinese economy. Figure 2.3 plots growth rates of GDP and CPI during 1978 and 2012. The average annual growth rate was approximately maintained at 9%, but there were some sharp drops, such as the recession in 1989, which was possibly due to a political event. It became relatively stable and smooth after 1992 when the market economy practiced in China. It is predicted that China's GDP will rank the first in the world by 2015 (Maddison, 2009). Most individuals hold the idea that the lower RMB exchange rate contributes to China's growth, and in turn, that growth helps to maintain a stable currency. Comparatively, CPI growth rate in China frequently fluctuates over time. The recession around 1989 was probably aroused from the political unrest. The sharp increase and decline around 1994 were due to the price reform. In 1993, the pricing mechanism reform and the deepening of opening door policy stimulated the upturn in goods prices. To manage the internal price, the government gradually strengthened the market scrutiny and implemented the managed floating exchange rate policy, which helped to bring the CPI back to normal. After the 1997 Asian financial crisis, the CPI in China turned on a moderate growth speed. Empirically, some studies find that CPI could be affected by changes in the RER. Fearing of floating exchange rate policy is significantly associated with lower CPI volatility (Sokolov et al., 2011).

Foreign trade in China has also experienced long term growth for decades. Since 2009, China has been the largest exporter and second largest importer in the world.

[10] Guideline for foreign exchange reserves management, IMF, 2004.

[11] SAFE news, State Administration of Foreign Exchange, "Report on the international balance of payments of the first-half year in 2012".

Figure 2.4 shows exports and imports in China over the period 1978 to 2012. It is apparent that China has been in a situation of trade surplus since 1994. The trade volume increased dramatically after China joined the WTO in 2001. A larger number of Chinese firms started investing overseas and selling their products in the global market. As demonstrated in the figure, there was a significant recession in China's foreign trade, which was due to the 2008 world financial crisis. After that, the growth of foreign trade in China continued. The historical statistics are consistent with the notion that exports drive the Chinese economy. And also, the research evidence shows that the exports of labour intensive products contribute to China's foreign trade in the short run (Ba and Shen, 2010). However, if a country always has a trade surplus in the bilateral trade, it has to rethink and make some adjustments to the currency policy.

Figure 2.5 depicts the foreign direct investment (FDI) of China.[12] The foreign capital inflows in China before 1990 was very small. The accumulated FDI from 1978 to 1984 was just $4.1 billion. When China exercised the market-oriented economy and deepened the opening door policy in 1992, foreign capital started flowing into China due to the nice investment environment and peaceful political process. As demonstrated in the graph, it maintained the growth momentum except for the slight slowdown during the 1997 Asian financial crisis and the 2008 world financial crisis.

From trade partners' perspective, the rise of China is bound up with the managed floating exchange rate regime. So they are overflowing with questions that are aiming to uncover the secret of China's growth. This also stimulates the author's interest in exploring the mystery. Based on the existing research evidence and the real situation in China, this chapter aims to answer the following questions: (1) Whether there is a long run equilibrium relationship between the RER and economic growth in China? (2) In the past decades, what has contributed to the stability of the Chinese currency and the continuous growth? (3) Were there structural changes in the currency policy reform in July 2005? (4) Does the correlation between the RER and economic growth remain constant after the great recession?

This study differs from previous studies in the following aspects: (1) the CVAR approach and its vector error correction model (VECM) are applied to investigate the long run equilibrium and short run dynamics between the RER and growth,

[12] In Figure 2.5, the data in 1984 was the accumulated data from 1978 to 1984.

respectively; (2) the structural break for the 2005 RMB policy reform is examined both inside and outside of the VECM; (3) the great recession test is conducted, and (4) the determinants of the RER include GDP, foreign reserves, foreign trade and foreign investment, which are also the growth indicators.

The framework of this chapter is constituted by the following parts. Theories of exchange rate determination is discussed in Section 2.2. Section 2.3 gives the literature on exchange rate dynamics. Data and econometric methods are discussed in Section 2.4. The long run equilibrium relationship and short run dynamics between RER and economic growth are explored using the CVAR approach and the VECM in Section 2.5. Section 2.6 summarises the key findings and the last section concludes the chapter.

2.2 Theories of Exchange Rate Determination

The very early approach to exchange rate determination focuses on the importance of the elasticities of demand for imports and exports, and on the exploitation of the conditions of improving the balance of trade in the context of devaluation (Lerner, 1936; Laursen and Metzler, 1950; Alexander, 1952). Since the 1960s, several main features of theories of exchange rate determination have been developed. Notably, they are the Mundell-Fleming model, the sticky-price monetary model, the flexible-price monetary model, equilibrium models and liquidity models, as well as the portfolio balance model.[13]

The Mundel-Felming model (Mundell, 1960, 1961a,b; Fleming, 1962) assumes that expectations are static and prices are fixed, which has an immense impact on the study of the exchange rate determination theory. The basic framework of the Mundell-Fleming model is constructed by three equations:

$$\begin{aligned} \dot{r} &= i - i^* \\ m &= \sigma r + ky - \theta i \\ \dot{y} &= \chi(\alpha + \mu r - \psi i - y) \end{aligned} \tag{2.1}$$

The first equation expresses the domestic price of foreign currency ($\dot{r}$) as the

[13] Only some basic ideas about theories of exchange rate determination are given in this section. Please look into the original literature for details.

difference of domestic (i) and foreign interest rates (i^*). m and y are the level of money supply and domestic income, respectively. A dot over a variable means a time derivative. This is referred as uncovered interest parity (UIP), which is expressed in continuous time with the assumption of perfect foresight. The second equation denotes the condition of domestic money market equilibrium. The consumer price level (p^c) is a geometric weighted average of foreign and domestic goods prices: $p^c = \sigma(r + p^*) + (1 - \sigma)p$, where σ is the weight for foreign consumer price index. The third equation associates changes in aggregate output with excess demand in goods market. Aggregate demand is a function of an autonomous component (α), a component of net export demand, an interest-rate-sensitive component and output.[14] Three cases are discussed in the perfect-foresight Mundell-Fleming model: the qualitative sadlepath solution, the effect of an increase in monetary policy, and the effect of an expansionary fiscal policy. The qualitative solution to the model indicates that the exchange rate responds to shocks which shift the saddlepath of the economy, and then converges towards the new equilibrium. An increase in money supply depreciates the exchange rate and increases output in the long run, where the exchange rate shows evidence of overshooting initially. In contrast, an expansionary fiscal policy has a net effect of a long-run appreciation of the exchange rate, with initial overshooting, and a long-run increase in output.

The sticky-price monetary model allows short-term overshooting of both nominal and real exchange rates above the long run equilibrium levels (Dornbusch, 1976). The model can also be seen in a three-equation structural model in continuous time, where domestic income and foreign variables are held constant:

$$\begin{aligned} \dot{r} &= i - i^* \\ m &= p + k\bar{y} - \theta i \\ \dot{p} &= \gamma[\alpha + \mu(r - p) - \bar{y}] \end{aligned} \tag{2.2}$$

A bar indicates a variable in long run equilibrium, ie, $\bar{y}$. The first two equations are similar to those in the Mundell-Fleming model, but domestic prices cannot be normalised to zero in the domestic monetary market equation. The third equation is now a fairly standard Philips curve relationship. The money market equilibrium

[14]Net export demand is a function of the nominal exchange rate since foreign and domestic prices are held constant in the model.

shows that prices must be proportional to money in the long run. And also, long run goods market equilibrium in the Philips equation indicates that the nominal exchange rate should be proportional to prices in the long run. Therefore, the long run purchasing power parity (PPP) form is said to hold in the Dornbusch model due to the money neutrality that often terms the model as the sticky-price monetary model. The qualitative solution to this model show that the saddlepath slopes down from left to right. In terms of the effect of a cut in the money supply, the net effect is a long run appreciation of the exchange rate, with an initial overshooting.

The Mundell-Fleming model assumes that output is demand determined and prices are fixed. In the Dornbusch model, output is at its natural level and prices adjust slowly to excess demand. The flexible-price monetary model (FPMM) is similar to the Dornbusch model, but prices are flexible and adjust instantly to the change in excess demand (Frenkel, 1976; Mussa, 1976). The FPMM is very attractive, but it needs a number of assumptions to achieve this simplicity. This model only concentrates on the money market. Domestic and foreign assets are assumed perfect substitutability in the model, and the domestic and foreign bond markets actually become a single market. In the foreign exchange market, the exchange rate responds freely to equilibrate supply and demand. Equilibriums in the goods market and the labour market are achieved through the assumption of perfectly flexible prices and perfectly flexible wages, respectively. The FPMM is unreservedly a market-clearing general equilibrium model which holds the assumption of continuous PPP among national price level.

Equilibrium models are an extension of the FPMM in which multiple traded good and real shocks are allowed to spread across countries. Stockman (1980) and Lucas (1982) explore the general equilibrium of a two-country model by maximising the expected present value of the agent's utility, subject to several constraints, ie, budget constraints and cash-in-advance constraints. In the equilibrium model, an increase in domestic productivity has two separate effects: the "relative price effect", which involves a reduction in the relative price of domestic output; and the "money demand effect", which trends to appreciate the domestic currency. However, the equilibrium level of the exchange rate will be affected if one country becomes relatively more productive, which means that the assumption of each economy holding exactly the same fractions of wealth in any firm, domestic or foreign, is violated. With regard to liquidity models of the exchange rate, researchers extend the equilibrium model framework by including the cash-in-advance constraint on agents. Agents in these models are required to hold cash to purchase goods and assets. In the example of two-country model, money supply and bond issue in each country are linked through government budget constraint. Agents' decisions on holding domestic and foreign currency will cause subsequent shocks to bond and money supplies that affect nominal interest rates and real interest rates, and this in turn affects the nominal and real exchange rates.

The portfolio balance model for determining the exchange rate has an assumption of imperfect substitutability between domestic and foreign assets, as well as the negligible wealth effects of current account imbalances (Dornbusch and Fischer, 1980; Branson, 1981). The exchange rate is the main determinant of the current account balance, which means that a deficit (surplus) in the current account balance is related to a fall (rise) in net domestic holdings of foreign assets, which affects the level of wealth, and the level of the demand for assets in turn influences the exchange rate. Therefore, the portfolio balance model is a dynamic model for determining exchange rates based on the interplay of asset markets, prices and the rate of asset accumulation, and current account balance. This allows us to differentiate the short-run equilibrium from the dynamic adjustment to the long run equilibrium.

2.3 Literature Review

When barter began in ancient times, human beings gradually deepened their understandings of exchange, and started to extend the trade-offs to other regions when they had the desires and needs on other goods which they could not produce. Nevertheless, foreign trade nowadays is more complicated and influencing than the barter in ancient times, since it is associated with the economic boom and currency stability. Research evidence suggests that an unstable currency usually has a significant impact on foreign trade and the local economy. Historically, economic recession and political events were the important factors affecting the foreign exchange, which have been studied after the First World War. In the twentieth century, exchange rate studies concentrated on exchange rate regimes and RER determinants, as well as relevant theories. The relationship between the exchange rate and economic growth has been the research focus in the new century. This section begins with a general review of research focus on exchange rates, which gives an overall perspective for understanding the research stream since the early twentieth century, then details the studies on the relationship between the exchange rate and economic growth, and finally gives the discussion on specific RMB exchange rate studies.

2.3.1 Research Focus on Exchange Rates

Exchange rate dynamics has been the core system of international currency and a intensely discussed topic in the field of economic and financial research for decades. Early studies largely focused on the correlation between foreign trade and the foreign exchange rate, as well as some basic theories, such as equilibrium exchange rate and exchange rate determination. The earliest study on exchange rate fluctuation and its impact on foreign trade was not in developed economies, but in developing economies (in Latin America). Williams (1919) has explored the foreign exchange fluctuation and its impact on international payments in Latin America (Argentina, Brazil, Chile and Uruguay) during the war time. These countries used credit exchange conventions as their intention of stabilizing exchange rates without resorting to gold shipments, but Williams found that these countries had a lower exchange rate compared with the level of pre-war years. After that study, the Purchasing Power Parity (PPP) doctrine was discussed by Angell (1922),[15] who has discussed the basic mechanism and process of international trade under inconvertible paper and gold standard.[16] The remarkable difference between two mechanisms was the comparative instability of foreign exchange under the inconvertible paper regime. The equilibrium exchange rate between two currencies (dollar and sterling) has been studied by Pigou (1922),[17] who investigates the precondition of equilibrium exchange and its impact on current norm of exchange. In certain circumstances, government intervenes in the foreign exchange market to get an equilibrium exchange rate and build up the investment environment. Few literature could be found in the 1930s except Graham and Whittlesey (1934), who have explored the impact of floating exchange rates on foreign trade and stability of goods prices. With the development of the equilibrium exchange theory, countries attempted to stabilize their currencies in the foreign exchange market. Based on the price disparity framework,

[15]Purchasing power parity (PPP) is an economic theory and a technique used to determine the relative value of currencies.

[16]Inconvertible paper money means that money is not convertible into gold or coins.

[17]The discussion on the equilibrium of exchange is different from the measurement of equilibrium exchange rate. The former requires a unit in one country shall exchange for a claim on a number of units in the other, while the latter refers to the equilibrium exchange rate determinants.

Garnsey (1945) presents the equilibrium exchange rate referencing to the comparative advantage criterion and the cost-price parity criterion. However, the seeking of equilibrium exchange rate should be carried out within a broad range rather than a single precise point (Young, 1947), judging by experiencing with previous rates and the gold standard. Metzler (1949) draws a conclusion from numerous studies that the elasticities of imports demand and exports supply play an important role in stabilising the exchange rate,[18] and the secondary movements of income.

In the 1950s, a number of studies focused on the impact of exchange rate policy. Single or multiple systems, floating or fixed rates? Most nations lingered on exchange rate systems and could not have a decisive decision. The cases for a floating exchange rate regime in France and Canada have been discussed by Eastman (1955). Although two countries suffered severe inflation in dissimilar circumstances, the free exchange mechanism had a equilibrating influence on their economies. Ames (1953) explores the linkage between the internal and domestic economic activities of the Soviet-type economies. Effective foreign exchange policy brings the prosperity of internal economy, while an inappropriate one harms foreign trade and economic stability. Learning from the experience of Canada, Thailand had implemented the multiple exchange rate system in the 1950s. Yang and Yang (1957) explicitly demonstrate the advantage of a multiple exchange rate system in Thailand after it gave up the fixed exchange rate policy.[19] Besides the country specific exchange rate policies, there were some theoretical analysis on the impact of exchange rate dynamics, for instance, Geary (1958) gives a simple solution to the problem of comparing the exchange rate and the purchasing power between currencies, and Smith (1954) reveals the effect of exchange rate adjustments on the living standard. Moreover, exchange rate dynamic mechanisms based on multiple systems have been explored by Polak and Liu (1954). They attempt to analyse the complication arising from the inclusion of more countries in the system under the circumstance of dynamic conditions. They conclude that the sufficient condition for stabilizing a three-country system is the following condition: for any pair of countries, the impact of the absolute product values on balances of each others are smaller than the impact on their own balances.

[18]In the study, the stability of exchange rate is defined as the sum of imports and exports elasticities, which should be equal to unity. It will be unstable if the sum of the elasticities is less or greater than unity.

[19]Canada and Thailand were the only two countries having a fluctuating rate rather than a fixed rate since the 1940s. Other countries still adopted the fixed exchange rate system.

Since the 1960s, countries around the world accelerated their speeds of economic development. Global and regional economies became increasingly interrelated and mutually affected. A number of studies on exchange rates appeared, especially the proactive macroeconomic policy under the circumstance of exchange rate fluctuations, such as the employment policy (Mundell, 1960), welfare cost of disequilibrium exchange rate (Hause, 1966), effective tariffs protection (Balassa and Schydlowsky, 1968), arguments on fiscal and monetary policies based on the floating and fixed exchange rate policies (Takayama, 1969), payments and trade restrictions associated with exchange rate policies (Leftwich, 1966), round table on exchange rate policy (Machlup et al., 1969), etc. In addition, there were a number of studies on exchange rate dynamics in Canada during the 1960s after the study of Rhomberg (1964), who mentioned that the currency policy had been actively concerned by Canadians since the end of the First World War,[20] such as capital flows responding to the fixed and flexible exchange rate (Stoll, 1967), forward exchange market based on different exchange rate policies (Stoll, 1968), and the impact of exchange rate changes on the prices of traded goods (Dunn, 1970).

From the 1970s to the 21st century, this section will only review several topics which were frequently discussed by researchers and policymakers. Generally, the research focus mainly lies in exchange rate policies and theories (Flanders and Helpman, 1978; Levin, 1979; Taylor, 1995; Chang and Velasco, 2000; Hernandez and Montiel, 2001),[21] discussions on the official intervention in the exchange rate market (Fischer and Zurlinden, 1999; Sarno and Taylor, 2001), exchange rate determination (Uz and Ketenci, 2010; Loría et al., 2010; Tsen, 2011), exchange rate fluctuation and forecasting (Dornbusch, 1976; Wilson, 1979), exchange rate and macroeconomic performance (Adam et al., 2001; Sokolov et al., 2011). In addition, the correlation between the exchange rate and other economic indicators were also widely explored previously in the literature, including the exchange rate, fiscal and monetary policy (Sachs, 1980; Bauer et al., 2009; El-Shagi, 2011), impact of exchange rate uncertainty on investment (Darby et al., 1999), exchange rate policy

[20]See: Michael D.Bordo. "Alternating Exchange Rate Regimes: The Canadian Experience, 1820-2000", and Lawrence Schembri, "Canada's Experience with a Flexible Exchange Rate in the 1950: Valuable Lessons Learned".

[21]More comprehensive discussion about the selection of a fixed or floating exchange rate regime in the 21st century was presented by Rose (2011), one of the findings from the paper revealed that similar countries choose totally different exchange rate policies did not exhibit big consequences for macroeconomics, such as economic growth and inflation, however, a number of studies find that the exchange rate regime has a negative or positive impact on growth.

and capital mobility (Hochreiter, 2000), relationship between exchange rates and stock prices (Bahmani-Oskooee and Sohrabian, 1992; Tian and Ma, 2010), the dynamic relationship between exchange rates and growth (Tharakan, 1999; Henry and Woodford, 2008; Harms and Kretschmann, 2009), etc. These findings strongly support the importance of foreign exchange rate, which not only plays an important role in the domestic growth, but also affects the regional and global economy. Exchange rate studies in China have a relative late start due to its economic backwardness and political unrest before the 1970s. However, the rise of China and its currency policy reforms in 1994 and 2005 have attracted significant attention from academics, policy-makers and practitioners, since they believe that China's growth is bound up with its currency policy.

2.3.2 Impact of Exchange Rate Regime on Economic Growth

The Chinese currency policy has been closely scrutinized by the international community for decades, as the RMB exchange rate is rigidly managed by the authorities, which leads to the non-tradable of the RMB in the foreign exchange market.[22] Previous studies on the impact of exchange rate regimes on economic growth are to find evidence of whether different exchange rate systems generate different impact on growth. Generally, flexible exchange rate policies have a positive impact on economic growth (Sokolov et al., 2011), while fixed exchange rate regimes have a negative impact on economic development (Levy-Yeyati and Sturzenegger, 2003). Added to that, intermediate exchange rate regimes are positively correlated with growth in emerging economies, but suffer from currency flexibility (Tu, 2012). Comparatively, exchange rate regimes do not show any significant impact on industrial economies which have a flexible exchange rate policy. Specifically, Harms and Kretschmann (2009) show that various classifications of exchange rate regimes produce fairly similar results in the group of developed countries, which have higher growth rates under a flexible exchange rate policy. While in developing countries and emerging markets, the currency policy of pegging to the USD and *de facto* stability in the exchange rate have a positive impact on growth. Moreover, official intervention has a negative impact on economic performance in the *de facto* classification. If a currency

[22]The international community criticizes the non-tradable of the RMB in the foreign exchange market, particularly when China experiences a continuous growth but trade partners are still in recession in recent years. The 2005 RMB policy reforms is believed to stimulate the Chinese economy. Therefore, this chapter revisits the effect of the 2005 RMB policy reforms.

is only pegged to the USD, it may hinder its growth. Benhima (2012) empirically finds that the higher the degree of dollarization, the more likely a negative impact on growth. Nevertheless, De Vita and Kyaw (2011) argue that different choices of exchange rate regimes have no direct impact on the long term economic growth in developing countries. After controlling for the monetary framework, the intermediate and flexible exchange rate regimes show no evidence of pro-growth than the fixed exchange rate policy. While Rose (2011) finds that it is difficult to figure out which kind of currency policy of an economy is in practice, since radically different exchange rate regimes selected by similar countries might not generate substantive consequences for macroeconomic discrepancies.

2.3.3 Relationship between RER and Economic Growth

RER did not play a major role in the economic growth analysis in the traditional closed-economy models (neoclassical growth models). Recent studies highlight the importance of RER in growth analyses (Eichengreen, 2007). The existing literature has found a positive relationship between RER undervaluation and economic growth, which tends to be much stronger in non-industrial countries (Rodrik, 2008). Applying an alternative classification and empirical approaches, Rapetti et al. (2012) find that the effect of currency undervaluation on growth is much larger and robust in developing countries, but the relationship is non-monotonic between RER undervaluation and per capita GDP, which are largely limited to the richest and least developed countries. Theoretically, the Balassa-Samuelson effect points out the existence of a long run relationship between productivity differentials and RER. Ito et al. (1999) examine the effect and find the prominent evidence in some Asia economies, and further claim that the application of Balassa-Samuelson hypothesis to a particular economy depends on the development stage of the economy. This effect is evident in advanced economies, but the analysis for emerging economies only weakly supports the effect (Edwards and Savastano, 1999). Compared with other emerging economies, Coudert and Couharde (2007) evidence the lack of Balassa effect in China and indicate that the RMB equilibrium rate is undervalued. Karadam and Özmen (2013) show that changes in the RER do not have any significant effect on advanced economies both in the long run and the short run, but the RER depreciation is contractionary in the long run in developing countries. Furthermore, Wong (2013) concludes that RER devaluation promotes growth but RER appreciation reduces growth in Malaysia. The positive relationship has also been found between RER and economic growth in Ghana (Attah-Obeng et al., 2013), but RER devaluation only stimulates growth in the short run.

The extant studies suggest that changes in the RER might produce negative or positive impact on economic growth. Researchers use different names for the RER fluctuation, like exchange rate misalignment, exchange rate uncertainty and exchange rate disequilibrium. Exchange rate misalignment is defined as the deviation of RER from its equilibrium value. Most studies conclude that a highly fluctuating exchange rate has a negative impact on economic growth (Vieira et al., 2013; Lizardo, 2009; Tharakan, 1999; Ndhlela, 2012; Aguirre and Calderón, 2005), while moderate volatile exchange rate changes have a positive impact on economic growth (Tarawalie, 2011; Vieira et al., 2013). Exchange rate undervaluation means that the currency is lower than it should be (the equilibrium exchange rate) or seriously depreciated. Exchange rate overvaluation designates that the exchange rate is higher than it ought to be. Moreover, exchange rate undervaluation (depreciation) has a positive impact on economic growth (Baldwin, 1961; Rodrik, 2008; Henry and Woodford, 2008; Abida, 2011; Yan and Yang, 2012), but overvalued exchange rate reduces growth (Elbadawi et al., 2012). Nevertheless, Gluzmann et al. (2012) hold different views when they examine the effect of an unevaluated currency on different components of GDP. Their findings show that undervalued currencies in non-industrial countries do not impact on export sectors, but promote greater domestic saving, investment and employment.

2.3.4 Literature on the RMB Exchange Rate

The announcement of a switch to a managed floating exchange rate policy in China in 2005 has inspired the interests of many scholars and policymakers. Although it was said that the RMB exchange rate would be set with reference to a basket of currencies with different weights, the *de facto* policy remains pegged to the USD (Shah et al., 2005; Frankel and Wei, 2007; Zeileis et al., 2010). In practice, the structural change of the 2005 RMB policy reform is of interest to researchers, but it is still a controversial issue. Some studies have found the existence of structural effects (Willenbockel, 2006; Shi et al., 2008; Zeileis et al., 2010; Xiang and Pan, 2011), while other studies claim the nonexistence of structural breaks (Shah et al., 2005; Zhiwen, 2011). Further, it was believed that the currency policy reform has contributed to the Chinese economy, while Ba and Shen (2010) find that China's growth is driven by the export of labour intensive products in the short run. This may lead to the increase in GDP in China to overtake the US as the largest economy in the world before 2015 (Maddison, 2009). However, China's growth mainly depends on factor accumulation rather than productivity growth (Feng and Wu, 2008). Although the international community has criticized the Chinese currency system, the managed floating exchange rate policy has played an important role in the regional economy, since it opens an evolutionary path towards regional currency stability and monetary cooperation in East Asia (Ma and McCauley, 2011).

In terms of the RMB equilibrium exchange rate, Tyers et al. (2008) suggest that the continuous inflow of financial capital appreciates the Chinese currency in the short run, while the labour force might appreciate the RMB in the long run. However, Wang et al. (2007) find that the RMB exchange rate fluctuates around the equilibrium level within a narrow band, which means that the RMB is not consistently undervalued. You and Sarantis (2012) find that the determinants of the RMB equilibrium exchange rate consist of trade, population, liquidity constraints and government investment.

In general, the extant literature on the nexus between the exchange rate and economic growth mainly focuses on the effects of exchange rate regimes on growth and exchange rate fluctuations on growth. Previous RMB exchange rate studies have discussed the exchange rate pass-through effect, particularly for the 2005 RMB policy reform. However, the long run equilibrium and short run dynamics between the RER and economic growth in China remain unanswered. The effects from foreign exchange reserves and foreign direct investment were ignored in these studies, since they were interested in the domestic exchange rate pass-through effects. Furthermore, the structural change in the currency policy reform in 2005 is still a controversial issue. The nexus between RER and economic growth after the 2008 great recession has not yet been explored. These are the questions to be discussed in this chapter.

2.4 Data and Econometric Methods

The monthly data used in this chapter are obtained from several official websites of China spanning the period from January 1994 to December 2012.[23] The selected variables consist of nominal GDP, nominal exchange rate of USD to RMB, the US and China CPI (the US CPI is collected from the International Monetary Fund (IMF)), foreign exchange reserves (FER), exports, imports and foreign direct investment (FDI). Before proposing the econometric methods for this chapter, this section makes a general description of the variable definition and construction, then introduces the cointegrated vector autoregressive (CVAR) model (also known as Johansen cointegration approach) and its vector error correction model (VECM) to explore the long run equilibrium and short run dynamics between RER and economic growth, respectively.

2.4.1 Data, Variable Definition and Construction

Data sources of these variables are detailed in Table 2.1. Some general introductions of these variables are presented as follows.

NER: Nominal exchange rate of USD to RMB (USD/RMB). To observe the long run equilibrium relationship, the inflation differentials between countries have been taken into account and the nominal exchange rate (NER) is changed into real exchange rate (RER). In this chapter, RER is defined as the adjustment of the NER for foreign and domestic price levels. Consumer price index (CPI) is commonly used as a proxy for the price level.[24]

GDP: Nominal GDP of China, which is announced each quarter by the Chinese government. China had an average annual growth rate of 9.8% between 1978 and 2012 (see Figure 2.3). The quarterly GDP will be applied to each month. Two approaches can be used in the transformation of the monthly GDP. One is taking the average of the quarterly GDP and equally assigns each month with the average value. Another method is directly taking the value provided for the corresponding quarter (Das et al., 2007). This chapter applies the second approach. The real GDP

[23]The data used in this chapter are obtained from several official website of China, namely the People's Bank of China, the National Bureau of Statistics of China, the State Administration of Foreign Exchange, the General Administration of Customs of the People's Republic of China and the Invest in China.

[24]In some studies, the bilateral RER depends on the ratio of the GDP deflators of two economies, $(p^Y(P^S, P^T))$ and P_i^Y: $RER_t = NER_t(\frac{p^Y(P^S,P^T)}{P_i^Y})$, where P^S and P^T are the indexes over all the targeted economy's traded and non-traded goods and services, respectively (Tyers et al., 2008).

(RGDP) in this chapter is calculated by adjusting the nominal GDP for inflation, denotes $RGDP = (NominalGDP \times 100)/CPI$.

CPI: Consumer Price Index of China, which reflects the change in price levels of goods and services consumed by households in a certain period. It is usually announced each month. China's annual CPI increases by 4% on average in the past three decades.[25] Commonly, market economies assume that the acceptable range of the increase in CPI should be between 2% to 3%. Serious inflation happens if CPI growth rate is more than 5%, which could be caused by the higher rate of economic growth.

FER: Foreign exchange reserves (also is known as foreign reserves). China owns a large amount of FER (see Figure 2.2), which was approximately at the volume of $3,300 billion by the end of 2012. Can the FER effectively contribute to the stability of the Chinese currency? This is questioned by many researchers and policy-makers, since they believe that the Chinese authorities are intervening the RMB foreign exchange market using its FER.

Exports and Imports: China has been the largest exporter and second largest importer in the world since 2009. In Figure 2.4, it is apparent that China has a long term trade surplus since China joined the World Trade Organisation (WTO), although there was a recession around 2008. It is the cheaper labour costs and raw materials in China that help the Chinese manufacturers to expand and sell their products overseas. Moveover, the continual openness in China also play an important role in stimulating exporting industries. In practice, the higher the degree of trade and financial openness, the more volatile the bilateral exchange rate is likely to be at domestic prices.

FDI: Foreign direct investment of China. To avoid the potential problems generated from only having a small sample, this chapter uses FDI to observe the impact of investment on RER.[26] The actual usage of FDI is used in this chapter. As shown in Figure 2.5, FDI reached a peak at $110 billion by the end of 2012, which maintained the growth momentum since 1978 but suffered recession during the 1997 Asian financial crisis and the 2008 world financial crisis.

[25] The benchmark of CPI is set as 100 in 1978.

[26] The monthly data for domestic investment of China is only available from January 1999. To keep the data consistent, FDI is collected for this chapter.

2.4.2 Econometric Methods

Previous literature on the dynamic relationship between the exchange rate and economic growth mainly focused on the correlation between exchange rate policies and growth, the nexus between RER and growth. The conventional research framework has two steps: (1) measuring the exchange rate volatility after the investigation of the equilibrium exchange rate, then (2) exploring the long run relationship between growth and exchange rate changes. Their intentions are to interpret the exchange rate determinants and the impact of different exchange rate regimes or exchange rate changes on economic growth. However, this chapter aims to explore the long run relationship between the exchange rate and economic growth, but will not measure the fluctuation in the exchange rate. This section starts with a discussion of the theoretical model and relevant hypotheses, then moves to the approaches about stationarity and cointegration tests.

2.4.2.1 Theoretical Model and Hypothesis

Since this chapter is interested in investigating the impact of economic indicators on RER, the dynamic RER equation is introduced and transformed from the equilibrium exchange rate function (Edwards, 1988; Edwards and Savastano, 1999) and exchange rate fundamentals function (Rodrik, 2008; Gluzmann et al., 2012). Equation (2.3) gives the expected form of the theoretical model and below parameters are expected signs of the coefficients.

$$\begin{aligned} lnRER_t = &\beta_0 + \underset{(+)}{\beta_1} lnRGDP_t + \underset{(+)}{\beta_2} lnFER_t + \underset{(-)}{\beta_3} lnImp_t + \underset{(+)}{\beta_4} lnExp_t \\ &+ \underset{(+)}{\beta_5} FDI_t + \underset{(+)}{\beta_6} D + \varepsilon_t \end{aligned} \tag{2.3}$$

The expected sign of the parameter (positive or negative) in the equation above indicates that the growth indicator might have a positive (negative) impact on RER, which means depreciating (appreciating) the RMB. This chapter assumes that the increase in RGDP, FER, exports and FDI will depreciate the RMB, and the increase in imports will appreciate the RMB. In order to test the structural break of the 2005 RMB policy reform, the dummy variable D is set at 1 if the calendar date is after

July 2005, otherwise D equals zero. The policy dummy is assumed to have a positive impact on RER. All variables are expressed in natural logarithms except the dummy (D).

In January 1994, the People's Bank of China (PBOC) started to allow the public to buy and sell RMB freely, but it was still a managed floating rate and the currency was only pegged to USD. This chapter does not set a dummy variable for the 1994 RMB policy reform due to the small sample. In July 2005, the PBOC announced the implementation of a managed floating exchange rate regime based on market supply and demand with reference to a basket of foreign currencies. Since then, the RMB exchange rate continuously experienced appreciation. Previous studies examined the structural break for the 2005 RMB policy reform, and this chapter would like to revisit the possible structural change in 2005 and its impact on the Chinese economy.

Note that equation (2.3) is the expected form of the long run association between RER and its determinants. The specific long run equilibrium relationship will be determined by the CVAR estimates. There should be no worries about the endogeneity issue in this equation. On the one hand, the right hand regressors of this equation are recorded in different accounts. Foreign reserves and FDI are included in the capital account, whereas imports and exports are listed in current account. On the other hand, the CVAR approach treats all variables as endogenous in the system (except for the dummy variable). The endogeneity problem is solved by considering a VAR system and the error terms could be whiten by including enough lags in the VAR.

2.4.2.2 Methods for Stationary Test

The aim of this chapter is to examine the long run relationship between RER and its determinants. The econometric methods used in the literature can be summarised into four categories: (1) a single equation estimated using the linear regression approach, such as the OLS and two stage IV estimators (Harms and Kretschmann, 2009; Levy-Yeyati and Sturzenegger, 2003; Rose, 2011); (2) dynamic single equation, which is the extension of single equation and more likely to be estimated using the GMM estimator (Elbadawi et al., 2012; Guillaumont Jeanneney and Hua, 2011; Benhima, 2012); (3) cointegration approach, such as Engle Granger (EG) two-step cointegration, Johansen and ARDL cointegration (Ndhlela, 2012; Tarawalie, 2011); and (4) other approaches with more advanced econometric methods, such as EGARCH (1,1) conditional mean and variance model (Kim, 1999), which is frequently used in measuring the volatility.

This chapter proposes the cointegrated VAR (CVAR) approach to estimate the RER-growth relationship. The CVAR approach requires all variables to be integrated of order 1, so the stationarity of these series need to be examined before the application of the cointegration approach. In testing for stationarity, the commonly used approach is the Augmented Dickey-Fuller (ADF) test. Superior to the Dickey-Fuller (DF) test, ADF test extends the AR(1) process of the DF unit root test to AR (p) process, which efficiently describes complex patterns contained in actual economic time series (Patterson, 2000; Harris, 1995; Dickey and Fuller, 1979). Another frequently used unit root test method is the Phillips-Perron (PP) test. It is known that the ADF and PP tests have lower power against the local stationary alternatives. These tests also suffer from severe size distortion when there are negative moving average (MA) terms during the data generating process (DGP) [27]. Moreover, the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) stationary test is more powerful than the ADF test for small samples and less susceptible to positive size distortion, but it is less powerful for larger size if observations are greater than 250. Differing to the ADF and PP tests, the null hypothesis of the KPSS test is that the series is stationary. In addition, the Ng-perron test relies on the local generalized least squares (GLS) detrending method, which has greater power than the ADF and PP unit root tests (Perron and Ng, 1996; Ng and Perron, 2001). The Ng-perron test shows less size distortion in the MA error terms compared with the standard ADF and PP tests. The lag truncation suggested by Ng and Perron is a modified information criterion which shows excellent properties of the M-tests. Recent development in the unit root test is the multivariate unit root test based on the vector error correction model (VECM) estimator of Johansen's likelihood ratio test (Johansen, 1988; Johansen and Juselius, 1990), that is the JLR test. This test has a more informative null and alternative hypothesis (Taylor and Sarno, 1998). They claim that this approach has somewhat better power than univariate unit root tests (the ADF and KPSS test). In order to get robust unit root test results, this chapter applies both the univariate unit root tests (ADF, KPSS and Ng-Perron test) and

[27] See Elliot, et al.(1996) and Ng and Perron(1996,2000)

the multivariate unit root test (Johansen test) to examine the stationarity of these series.

The Dickey Fuller (DF) unit root test is testing the null hypothesis that a series has a unit root (non-stationary). However, a series y_t actually follows the multiple autoregression process, then the autocorrelated error terms are not valid in the DF test, since it is built upon the white noise assumption. Thus, a p-th order AR process of series y_t with deterministic components (constant and trend) has the following expression (Dickey and Fuller, 1979; Dickey and Pantula, 1987).

$$\Delta y_t = \psi^* y_{t-1} + \sum_{i=1}^{p-1} \psi_i^* \Delta y_{t-i} + \mu + \gamma t + u_t \quad u_t \sim iid(0, \sigma^2) \tag{2.4}$$

Equation (2.4) is popular with researchers in testing unit roots. Where $\psi^* = (\psi_1 + \psi_2 + ... + \psi_p) - 1$. If ψ^* equals zero, against the alternative hypothesis that ψ^* is less than zero, then y_t is said to be non-stationary. The t-statistic can be calculated via $\hat{\psi}^*/se(\hat{\psi}^*)$. For the ADF test, the optimal lag length is important. If p is too small, the test will be biased. If p is too large, the power of the test will suffer. Schwert (2002) suggests that the optimal lag length can be calculated via the formula: $\tilde{p} = int[12 \times (T/100)^{0.25}]$ (T is sample size).

The KPSS test differs the null of the ADF test is that the series is stationary (against the alternative of a unit root) (Kwiatkowski et al., 1992). This test decomposes a series into a model of deterministic trend (ξt), a random walk (γt) and a error term (εt):

$$y_t = \xi t + \gamma t + \varepsilon t \qquad and \quad \gamma t = \gamma t - 1 + ut \tag{2.5}$$

Where $u_t \sim iid(0, \sigma_u^2)$. The null hypothesis is simply set as $\sigma_u^2 = 0$. Saving the residuals from the OLS regression on equation (2.5) and computing the cumulative residual function $S_t = \sum_{s=1}^{n} e_s$. Then the LM statistic is given by $LM = \sum_{t=1}^{T} S_t^2/\hat{\sigma}^2$, and $\hat{\sigma}^2$ is an estimate of the error variance (RSS/T).

Applying the local GLS detrending approach and the modified Akaike information criterion (M-AIC), Ng and Perron (2001) improve the Phillips-Perron (PP) test (Phillips and Perron, 1988) and extend the ERS test (Elliott et al., 1996) using a class of tests, which are denoted as M-tests. For the DGP:

$$y_t = d_t + u_t, \quad u_t = \rho u_{t-1} + v_t \tag{2.6}$$

Where $v_t = \psi(L)e_t = \sum_{j=0}^{\infty} \psi_j e_{t-j}$, $d_t = \zeta' z_t = \sum_{i=0}^{p} \zeta_i t^i$ for p=0,1. For any given series $\{z_t\}_{t=0}^{T}$, $(z_0^{\bar{\alpha}}, z^{\bar{\alpha}_0}) \equiv (z_0, (1-\alpha\bar{L})L)z_t$ is defined for the selection of $\bar{\alpha} = 1+\bar{c}/T$. Elliott et al. (1996) define the GLS detrending series as: $\tilde{y}_t \equiv y_t - \hat{\zeta}'_t$. $\bar{c}$=-7.0 for p=0, and $\bar{c}$=-13.5 for p=1, respectively. Defining the term $k = \sum_{t=2}^{T}(Y_{t-1}^d)^2/T^2$, then the M-statistics of the Ng-Perron test are given below:

$$\begin{aligned}
&MZ_\alpha^{GLS} = (T^{-1}(Y_T^d)^2 - f_0)/(2k) \\
&MZ_t^{GLS} = MZ_\alpha^{GLS} \times MSB^{GLS} \\
&MSB^{GLS} = (k/f_0)^{\frac{1}{2}} \\
&MPT_T^{GLS} = \begin{cases} (\bar{c}^2 k - \bar{c}T^{-1}(Y_T^d)^2)/f_0 & if z_t = \{1\} \\ (\bar{c}^2 k + (1-\bar{c})T^{-1}(Y_T^d)^2)/f_0 & if z_t = \{1, t\} \end{cases}
\end{aligned} \tag{2.7}$$

All these M-tests are based on s_{AR}^2, which is an autoregressive estimation of spectral density starting from zero of v_t. It is expressed as:

$$s_{AR}^2 = \frac{\hat{\sigma}_k^2}{[1-\gamma(1)]^2} \tag{2.8}$$

Where $\hat{\sigma}_k^2 = (T-k)^{-1} \sum_{t=k+1}^{T} \hat{e}_{tk}^2$ and $\gamma(1) = \sum_{i=1}^{k} \gamma i$. The coefficient γ_i and residuals $\hat{e}_{tk}^2$ can be obtained from equation (2.5) applying the OLS estimation. The lag length k suggested in the Ng and Perron test can be determined by the modified Akaike information criterion(M-AIC):

$$MAIC(k) = ln(\hat{\sigma}_k^2) + \frac{C_T(\tau_T(k) + k)}{T - k_{max}} \tag{2.9}$$

The ADF, KPSS and Ng-Perron test are univariate unit root tests. They are said to notoriously own lower power and suffer from size distortion in the DGP (Taylor and Sarno, 1998; Crowder, 2001). Therefore, the multivariate unit root test has been proposed by Taylor and Sarno (1998) based on Johansen's VECM estimator (Johansen and Juselius, 1990). The Johansen's multivariate unit root test has better power than univariate unit root tests and a more informative alternative hypothesis than panel unit root tests. Since the Johansen stationary test is a VECM estimator and based on the vector autoregressive (VAR) process, this chapter will discuss the test in the CVAR model.

2.4.2.3 Cointegrated VAR (CVAR) Model

Taking into account the functional form and properties of time series data, the cointegration approach should be an appropriate method for exploring the long run relationship between RER and economic growth. However, there are at least three kinds of cointegration approaches. Each of them applies to different situations pursuant to the stationarity of variables. The Engle and Granger (1987)(EG) test for cointegration is suitable for testing the equation with two variables, which is known as the EG two-step approach. Another cointegration method is the autoregressive distributed lag (ARDL), which is feasible for exploring the potential long run relationship irrespective of the integration order of variables.

The EG two-step cointegration approach is notable for the drawback of left hand side variable since we do not initially know the left hand side variable . Once variables are more than two, the EG approach is inappropriate for the single equation. In this chapter, there are six variables and one exogenous variable in the system, then the multivariate cointegration approach applies to this case, that is the cointegrated VAR (CVAR) approach (Johansen, 1988; Johansen and Juselius, 1990), also known as the Johansen cointegration approach, which requires that all variables in the system should be integrated I(1). The CVAR approach integrates all variables into a system with different restrictions on the constant and trend. The CVAR approach is formulated into a vector error correction representation:

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + ... + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi X_{t-k} + \mu + \delta_t + \varepsilon_t \quad (2.10)$$

Where X_t is a $n \times 1$ matrix of variables and Γ_i is a $n \times n$ matrix of parameters. $\Gamma_i = -(I - A_1 - ... - A_i), (i = 1, ..., k-1)$, and $\pi = -(I - A_1 - ... - A_k)$. The system includes the information of both the long run and short run adjustment to changes in X_t, which can be estimated from $\hat{\pi}$ and $\hat{\Gamma}_i$, respectively. In the matrix $\pi, \pi = \alpha \times \beta, \alpha$ indicates the speed of adjustment to disequilibrium and β denotes the coefficient of the long run relationship.

As equation (2.10) represents, CVAR test for cointegration is testing the reduced rank $\pi(\pi = \alpha\beta\prime)$, which is estimated by the maximum likelihood function. The standard likelihood ratio is computed by comparing the log of maximized likelihood function of the restricted model with the unrestricted model. The test for cointegration is to test the number of non-zero eigenvalues, which means to examine the number of r linearly independent columns in π. This implies that the likelihood ratio test equals the test of non-zero eigenvalues. The notable test for cointegration is trace test, which is given by: $\lambda_{trace} = -2log(Q) = -T\sum_{i=r+1}^{n} log1 - \hat{\lambda}_i, r = 0, 1, ..., n-1$. Where Q is equal to restricted maximized likelihood divided by unrestricted maximized likelihood (Johansen et al., 1992). For the null hypothesis $H_0 : \lambda_i = 0, i = r+1, ..., n$, trace test tests the null that $r = q(q = 1, 2, ..., n-1)$ against the alternative that $r = n$ (n is the dimension of VAR system). Another test for the reduced rank is the maximum eigenvalue test (λ_{max}), given by: $\lambda_{max} = -Tlog(1 - \hat{\lambda}_{i+1}), r = 0, 1, ..., n-1$. This test differs from trace test in the null hypothesis (there are r cointegration vectors) against the alternative hypothesis (there are $r+1$ eigenvalues).

Besides univariate unit root tests, this chapter also examines the stationarity of all series in the cointegration system. The test of unit root using the CVAR approach is to test the hypothesis that $r = p$. The distribution of λ_{max} depends on the specification of constant μ and trend δ in equation (2.10). The moving average representation of equation (2.10) is given as:

$$X_t = C\sum_{i=1}^{n}\varepsilon_i + C\mu t + \frac{1}{2}C\delta t^2 + C^*(L)(\varepsilon_t + \mu + \delta t) \tag{2.11}$$

Where $C = \beta_{\perp}(\alpha'_{\perp}(I - \sum_{i=1}^{k-1}\Gamma_i)\beta_{\perp})^{-1}\alpha'_{\perp}$ and $c^*(L)$ is a matrix polynomial. $\alpha_{\perp}$ is the orthogonal complement to the error correction and $\beta_{\perp}$ is the complement to cointegration space. To impose different deterministic specifications, δ and μ are decomposed into:

$$\begin{aligned} \delta &= \alpha\delta_1 + \alpha_{\perp}\delta_2 \\ \mu &= \alpha\mu_1 + \alpha_{\perp}\mu_2 \end{aligned} \tag{2.12}$$

In equation (2.12), δ_2 are the coefficients of a $(p-r)$ dimension vector of quadratic trends; δ_1 are the linear trend coefficients of r dimension vector in the cointegration space; μ_2 are the linear trend slops of $(p-r)$ dimension vector and μ_1 are the intercepts of r dimension vector. The deterministic restrictions of equation (2.10) is carried out by imposing restrictions on the four components ($\delta_1, \delta_2, \mu_1$ and μ_2).

- Type 1. No restrictions on the four components. The quadratic trend and linear trend are allowed in the levels of the series and the inferencing data, respectively. The hypothesis of this specification is denoted $H_0(r)$.

- Type 2. $\delta_2 = 0$, but other components are unrestricted. The linear trend is included in the cointegration space, then it is trend stationary but with quadratic trend excluded in the system. This specification is denoted $H_0^*(r)$.

- Type 3. $\delta_1 = \delta 2 = 0$ and with μ_1 and μ_2 unrestricted. It imposes trends in the levels of these series but these trends are eliminated by the cointegration vectors. This test is denoted $H_1(r)$.

- Type 4. $\delta_1 = \delta_2 = \mu_2 = 0$, but μ_1 unrestricted. It is a restriction of non-zero constant in the cointegration space but all trends in the levels are excluded. This test is denoted $H_1^*(r)$.

- Type 5. $\delta_1 = \delta_2 = \mu_1 = \mu_2 = 0$. This does not allow any trends and constants in the cointegration space, which is denoted $H_2(r)$.

The likelihood ratio test (LR) for testing the deterministic restrictions is proposed by Johansen and Juselius (1994). This approach is to test the null $H_i(r)$ against $H_i^*(r)$ or $H_{i+1}^*(r)$ against $H_{i+1}(r)$. The r largest eigenvalues are applied in the LR test while testing $H_{i+1}(r)$ against $H_i^*(r)$.

$$
\begin{aligned}
-2ln\pounds\{H_{i+1}(r)|H_i^*(r)\} &= T\sum_{j=1}^{r} ln[\frac{1-\hat{\lambda}_{j,i}^*}{1-\hat{\lambda}_{j,i+1}}] \\
-2ln\pounds\{H_i^*(r)|H_i(r)\} &= -T\sum_{j=r+1}^{p} ln[\frac{1-\hat{\lambda}_{j,i}^*}{1-\hat{\lambda}_{j,i+1}}]
\end{aligned}
\tag{2.13}
$$

Two formulas above give the LR test and the alternative test. The distribution of two tests are χ_r^2 and χ_{p-4}^2, respectively. The Johansen LR test together with the 5 types of restrictions above is called multivariate unit root test, which tests the stationarity of the cointegration space as a whole.

It is easy to carry out the cointegration test, but it is hard to identify the cointegrating vectors. This chapter mainly applies the recursive test of constancy approach to examine the stationarity of cointegrating vectors (Juselius, 2006). The first step of the forward recursive test is to estimate the model with selected baseline sample, and then recursively test whether the more recent observations have followed the same model.[28] The log likelihood statistic of the recursive test is given by:

$$Q_T(t_t) = \frac{t_1}{T}\sqrt{\frac{T}{2P}}[\frac{1}{t_1}\sum_{i=1}^{t_1} l_i(\hat{\theta}_i)] - \frac{1}{T}\sum_{i=1}^{T} l_i(\hat{\theta}_T) = \frac{t_1}{T}\sqrt{\frac{T}{2P}}(log|\hat{\Omega}_{t_1}| - log|\hat{\Omega}_T|) \quad (2.14)$$

Where $l_i(\theta) = -2log f_\theta(x_i|x_{i-1}, ..., x_{i-k} = log|\Omega| + \varepsilon_i'\Omega^{-1}\varepsilon_i$. If the test rejects the null of constancy, all subsequent tests may cease to have a meaning. The test is derived under the null of constant parameter up to time $T_1 + t_1$. If there is a break point at $T_1 + t_1$, then the remaining tests are derived under an incorrect hypothesis. In order to identify cointegrating vectors, this chapter makes a brief analysis of the recursive trace statistic, recursively calculated eigenvalues and its log transformed eigenvalues, as well as the max test of beta constancy, which are all based on the forward recursive test.

This chapter is also interested in examining the short run dynamics between RER and economic growth, particularly in testing the structural change in the 2005 RMB policy reform. This can be carried out in the VECM. Based on the cointegration framework, there might exist weakly exogenous and insignificant variables in the cointegration space. We can condition on the set of the I(0) variables D_t in the VECM, which will only affect the equilibrium in the short run. Thus, it is possible to rewrite equation (2.10) as the following equation (assume k=2):

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \alpha\hat{\beta}_1' + \Psi D_t + \varepsilon_t \quad (2.15)$$

Where D_t is included in the system to observe short run effects from exogenous variables, such as policy interventions. In this chapter, the dummy D_t is used to examine the impact of the 2005 RMB policy reform on the Chinese economy.

[28]The forward recursive tests is to test the selected baseline sample from the first part of the sample period.

2.5 Empirical Analysis

This section gives the empirical analysis of the relationship between RER and economic growth in China. To begin with, this section tests the unit roots of all variables using both the univariate unit root test and multivariate unit root test. Second, the cointegration analysis is carried out using the CVAR approach. Third, several methods are applied to identify cointegrating vectors, one of the important approach for this chapter is the recursive test. Fourth, the short run dynamics between RER and economic growth equation are estimated in the VECM. Building upon the VECM, the structural break of the 2005 RMB policy reform are examined. Fifth, the impulse response analysis of the RER equation is represented. Finally, this chapter tests the effect of the 2008 world financial crisis on the RMB exchange rate.

2.5.1 Data Transformation and Unit Root Test

Since the stationarity of a series can strongly affect its behaviour and properties, the standard assumption for asymptotic analysis will be invalid if non-stationary variables are included in the regression model. Therefore, we need to check the stationarity of these variables.

An intuitive examination of plots of these variables are shown in Figure 2.6, which shows that some variables have a zigzag trend, which implies the existence of seasonality, such as RGDP, exports, imports and FDI. So a seasonal adjustment in these series is carried out to separate the drift and cyclical components using trend decomposing methods.[29] To remove the potential heteroskedasticity from the residuals, all series are expressed in logarithmic form. The lower part of Figure 2.6 gives plots of the logarithmic series, all these series have constant means. Figure 2.7 shows plots of the first-differenced data. All of them mimic a white noise process, which implies the stationarity of these variables.

Table 2.2 reports sample moments and correlations of these series. If the skewness and kurtosis are around 0 and 3, respectively, we can say that the data is normally distributed. Alternatively, if the Jarque-Bera (JB) test accepts the null, then the sample follows a normal distribution.[30] In Table 2.2, the kurtosis for RGDP,

[29] Seasonal adjustment is to get rid of seasonal components in time series in order to truly explore objective laws of economic time series.

[30] Jarque, Carlos M.; Bera, Anil K. (1980). "Efficient tests for normality, homoscedasticity and serial independence of regression residuals". Economics Letters 6(3): 255-259.

foreign exchange reserves, exports, imports and FDI are far away from 3, so they are not normally distributed, although their skewness are close to zero. Added to that, JB values reject the null, which indicate the non-normality of the five variables. Table 2.2 also presents the correlation coefficients of these variables. Negative correlations exist between RER and its determinants, while the remaining correlation coefficients are positive. The highly correlated indicators might imply the potential multicollinearity of these series.

Univariate unit root tests are carried out in this section, while the multivariate unit root test will be implemented in the cointegration analysis section. Table 2.3 and Table 2.4 report unit root test results in both their level and first-differenced forms. In testing for stationarity, each test is carried out with two different restrictions, which are the inclusion of a constant, and both constant and trend terms, respectively. The ADF and KPSS tests are reported in Table 2.3. For both cases, these series are found to be stationary in their first differences, except FDI is trend stationary in level in the ADF test while including restrictions of both the constant and the trend. However, the Ng-Perron approach gives ambiguous results as shown in Table 2.4. Only the RER and FER reject the null at 10% and the 5% level at their first differences when a constant is included in the test. The M-statistics of other variables cannot reject the null simultaneously. A possible explanation for this could be the linear DGP of the Ng-Perron test. Although the Ng-Perron test has properties of greater power and less size distortion, the test could be biased in its linear DGP (Kapetanios et al., 2003). Table 2.5 gives a summary of unit root test results.

2.5.2 CVAR Test for the Long Run Relationship

The Ng-Perron approach represents ambiguous results for the stationarity test. We need to further check the stationarity of these variables, since the CVAR approach requires all variables to have an integration order of I(1). Before the cointegration test, the multivariate unit root test is carried out to examine the integration order of these variables in the cointegration system. Table 2.6 gives the multivariate unit root test for stationarity. 2 lags are initially selected,[31] then we subsequently

[31] According to the Ljung-Box Q-statistics, a lag truncation choice of $k = 2$ is sufficient to remove all statistically significant residual autocorrelation from the VAR residuals, see Crowder (2001).

increases one lag until lag 8, but none of these statistics can reject the null at the 5% level, which means that the cointegration space is not stationary in levels. However, the first differences of these variables are stationary in the multivariate unit root test (not reported), which suggest the integration order of I(1) of the cointegration system. This means that the CVAR test for cointegration is appropriate in this chapter.

The lag length selection for the CVAR approach really matters for the number and stationarity of cointegrating vectors. One way for determining the optimal lag is referring to the lag length of the same dimension of the VAR model. Another method for the lag length selection is choosing the shortest lag which produces serially uncorrelated residuals. This chapter determines the lag length with the combination of two methods. The lag structure in the VAR test suggested by AIC, SIC and likelihood ratio (LR) statistics are 2, 1, 3 lags, respectively, but the residuals behave much better when 3 lags are selected. Thus, the optimal lag length for the CVAR test should be 2 lags. The default deterministic assumption of an intercept but no trend is selected for the CVAR test, since all these variables are stationary in first differences. The stochastic trends and deterministic trends in the data can be removed by the deterministic cointegration restrictions.

However, the asymptotic critical value for the CVAR approach is really indicative since the original tabulated critical value does not take into account dummy variables in the deterministic part of the multivariate system. In the specification of additional exogenous variables, the commonly discussed variables are seasonal dummies. Johansen (1995) suggests that the conventional seasonal dummy variables can shift the mean without contributing to the trend. If standard 0-1 dummy variables are included as exogenous variables, it will affect both the mean and the trend of the level series X_t.[32] The level series in the cointegration system are modified and the critical values are invalid for the cointegration test, then the final test results will be biased. Therefore, the intention of testing the structural change in the 2005 RMB policy reform by including a dummy in the cointegration system is not suitable. 2 lags and the restriction of linear constant without trends are included in the cointegrating space. Table 2.7 and Table 2.8 represent the trace test and maximum eigenvalue tests for the cointegration rank, respectively.

The trace test for cointegration rank indicates that there are 2 cointegrating

[32]See the manual for Eviews 7, p.688.

equations in the system. Table 2.8 reports the maximum eigenvalue test for cointegration. The λ_{max} statistic tests whether $r = 0$ against $r = 1$, or $r = 1$ against $r = 2, , r = 5$ against $r = 6$. The null hypothesis of no cointegration vector among these variables is rejected at the 5% level, which indicates the existence of 1 cointegrating vector. The characteristic roots are reported in Table 2.9, the largest unrestricted root for $r = 2$ is 0.975, $r = 3$ is 0.967, $r = 4$ is 0.971 and for $r = 5$ is 0.981, respectively. The differences between these unrestricted roots are small and do not indicate obvious preferences between two alternative cointegration ranks.

2.5.3 Identifying Cointegrating Vectors

As the CVAR estimation shows, the trace test suggests that there are 2 cointegrating vectors, but maximum eigenvalue test indicates that there is only one cointegrating vector in the system. We need to further identify these cointegrating vectors since the two tests give ambiguous results. Cheung and Lai (1993) suggest that the trace test presents more robust results in both the skewness and excess kurtosis of the residuals than the maximum eigenvalue test according to their Monte Carlo experiments. The trace test is often criticized for its bias in accepting too many cointegrating vectors, which is an over-sized test. A large number of studies argue that there might be substantial size and power distortions in the cointegration test, since the asymptotic distributions are poor approximations of the true distribution due to the small sample (Juselius, 2006). While Johansen and Juselius (1990) suggest that we could examine the true and stationary cointegrating vectors based on our own choice. This chapter takes into consideration the stability of residuals for identifying cointegrating vectors. Building on the conventional cointegration approach, if the residuals of the regression model are integrated I(0), then the cointegrating vector could be accepted, which is known as the Engle-Granger (EG) two-step approach (Engle and Granger, 1987). Moreover, to accurately identify the cointegration relationship, Juselius (2006) suggests to use the combination of standard analysis and other available information. Generally, five types of information can be used to identify the cointegrating vectors: (1) examining the characteristic roots; (2) the significance of the adjustment coefficients; (3) the recursive graph of trace estimates; (4) plots of cointegration relationships, and (5) the economic interpretation of cointegrating vectors. This chapter checks the stationarity of these cointegrating vectors by applying these methods suggested above.

2.5.3.1 Checking the Stationarity of Cointegrating Vectors

To carry on the stationary test of cointegrating vectors, we plot the cointegration graph to check whether they are stationary.[33] Figure 2.8 represents plots of two cointegration relationships. Intuitively, the second cointegrating vector appears to be more stationary than the first cointegrating vector. The cointegration graph has a big jump around mid-2005, which reflects the impact of the 2005 RMB exchange rate regime reform. This could be used to explain why many researchers are interested in the examination of structural breaks in that period, as they believe that the reform has an important impact on the Chinese currency and the Chinese economy (Willenbockel, 2006; Shi et al., 2008; Zeileis et al., 2010).

Figure 2.9 presents a different version of those cointegration relationships. Vector $\hat{R}_{kt}$ is used instead of the $\hat{\beta'}_i x_t$ (X-form) , where x_t captures the short run dynamics in the cointegration test. $\hat{R}_{kt}$ is equal to x_t but in which all the short run dynamic effects are removed. Where $R_{kt} = x_{t-k} - (\hat{T}_1 \Delta x_{t-1} + ... + \hat{T}_{k-1} \Delta x_{t-k+1})$ (refer to R-form). The R-form graphs are more stable than the X-form over the sample period, since the degree of freedom of the X-form graph is fewer than the R-form. Moreover, no short run shock is included in the R-form cointegration relationship. Intuitively, the two cointegration relationships in Figure 2.9 show that the two cointegrating vectors are stable in the long run, which implies that r=2. Further, two graphs are not quite different, therefore, it is not necessary to check the integration order of I(2) in the data set,[34] and then we can continue to identify these cointegrating vectors using other approaches.

2.5.3.2 Forward Recursive Tests

The recursive test is a group test, including the test of eigenvalues λ_i, transformation of eigenvalues, log-transformed eigenvalues and the fluctuation test (Juselius, 2006). These tests give the information on constancy and non-constancy of the individual cointegrating vector.

[33] This chapter mainly introduces the recursive test for identifying cointegrating vectors.

[34] When the graph of $(\hat{\beta}'_1 x_t)$ and $(\hat{\beta}'_1 \hat{R}_{kt})$ is quite different, Johansen and Juselius (1994) suggest to check whether the data vector is I(2) or not.

Figure 2.10 shows both the X-form and R-form model of the recursive calculated trace tests.[35] The test is scaled by the 95% quantile of the asymptotic distribution. The upper panel of this figure is a recursive estimation of the full model (X-form). The lower panel is the recursive estimation of the R-form model, which shows a little more stability than the upper panel, but both models indicate the instability of the short run coefficients over the sample period. Further, this figure explains the size and power of the trace test. At the beginning, we can accept the existence of one cointegrating vector. To accept r=2, we have to wait until mid-2005 since the trace statistics are not stable over the period 1997 to 2005. This further confirms the reality that the Chinese currency becomes more stable since the 2005 RMB policy reform.

Figure 2.11 plots the recursively calculated eigenvalues with the 95% confidence bands from the unrestricted VAR model. From this graph, we can see that two eigenvalues are stay within the 95% bands for all periods, except the baseline sample periods. λ_1 and λ_2 are quite large at the beginning of the recursion, then decline until they maintain a stable value around 2005. Further, the log transformed eigenvalues are presented in Figure 2.12, which shows symmetrical confidence bands for the two eigenvalues. The lowest part of the figure is the weighted sum of the two eigenvalues. The individual eigenvalue fluctuation test is a recursively calculated constancy test. As Figure 2.13 demonstrates, the first eigenvalue shows a considerable degree of constancy. The second eigenvalue is reasonably constant over the sample period except the X-form model in the first several years. The last test is the combination of the two cointegrating vectors, which indicates the non-constancy of the cointegration relationship around 2002 in the X-form. Strictly speaking, we can accept the first eigenvalue in the cointegration space.

Testing the constancy of the cointegration space is another important way to identify the β structure, which is also an indicator for observing the change of the cointegration relationship. Figure 2.14 presents the max test of beta constancy. Both models are under the critical line of 1.0 for the sample period (1997:01-2012:12) except the constancy of the R-form is rejected around 1999. This test is very conservative and there is strong evidence of non-constancy if the test is rejected.

The last test of the recursive test family is the test of β_t equals known beta, which

[35]The recursive test is based on the baseline sample of 1994:01-1997:01, which is a recursive forward test.

is a method for testing whether the constancy of the cointegrating vector is actually acceptable. The parameters are constant only if the statistics are smaller than the critical value. Figure 2.15 reveals that the constancy of both the X-form and R-form model is rejected within a certain period. The X-form model test becomes relatively stable after 2003 and the constancy of the R-form test could be accepted after 1999. This means that the two cointegrating vectors from the trace test are only somewhat constant but not completely constant over the sample period.

2.5.3.3 Interpreting Cointegrating Vectors

To identify the cointegrating vectors suggested by the trace test, this chapter has checked the stationarity of the cointegrating vectors, the stability of cointegration relationships, the recursive estimates of eigenvalues and the test for constancy in the cointegration space. These tests are really indicative since some statistics support the stationarity of these cointegrating vectors while other tests show that these eigenvalues are problematic. The last resort would be the economic interpretation and significance of the coefficients of cointegration relationships. The identified cointegration relations from the trace test are the following:

$ecm_1 = lnRER + 2.811 lnFER + 4.298 lnImp - 6.549 lnExp - 3.673 lnFDI + 4.066$

$ecm_2 = lnRGDP + 7.022 lnFER + 11.175 lnImp - 17.837 lnExp - 10.295 lnFDI + 17.697$

Normalizing the two cointegrating vectors (t-statistics are reported in parentheses):[36] The t-statistics of the two equations are greater than 3, which indicate the significance of these coefficients.

$$lnRER = -4.066 - \underset{(-4.993)}{2.811}\, lnFER - \underset{(-4.04)}{4.298}\, lnImp + \underset{(4.698)}{6.549}\, lnExp + \underset{(6.225)}{3.673}\, lnFDI + \varepsilon_1 \tag{2.16}$$

$$\begin{aligned} lnRGDP = &- 17.697 - \underset{(-4.551)}{7.022}\, lnFER - \underset{(3.838)}{11.175}\, lnImp + \underset{(4.671)}{17.837}\, lnExp \\ &+ \underset{(6.359)}{10.295}\, lnFDI + \varepsilon_2 \end{aligned} \tag{2.17}$$

As the two equations reveal, there is no direct nexus between RER and RGDP according to the CVAR estimates. Both cointegration relationships are reasonable

[36] This chapter is interested in the RER and RGDP equation, so the RER and RGDP are put on the left hand side of the equations when normalizing cointegrating vectors.

and the coefficients are statistically significant. In the RER equation, the cointegrating vector reveals that exports have a positive impact on RER and that imports have a negative impact on RER. With other factors being constant, a 1% increase in imports leads to a decrease (appreciate) in RER by 4.298%. While a 1% increase in exports increases (depreciates) RER by 6.549%. The impact of exports is a little larger than imports in magnitude, which is related to the situation of continuous trade surplus in China. Moreover, FDI has a positive impact on the Chinese currency. A 1% increase in FDI causes RER to increase (depreciate) by 3.673%. Exports and FDI jointly helps reduce the fast appreciation of the RMB. This is consistent with the current situation of the Chinese currency that exports and foreign investments depreciate the RMB, whereas imports and FER appreciates the RMB. The historical statistics show that the RMB exchange rate has appreciated about 40% since 1994, but many economists still believe that the lower RMB exchange rate has harmed trade partners' economies. The international community criticises the slow pace of RMB appreciation and urges the Chinese authorities to quicken the reform of the RMB exchange rate. Nevertheless, some economists think that the dramatic appreciation of the RMB will disrupt its exports industry and lead to widespread layoffs (Morrison and Labonte, 2011).

Equation (2.17) presents the RGDP equation, it demonstrates that China is currently indeed an export-driven growth. The inflow of foreign capital also plays an important role in rejuvenating the Chinese economy. To accurately identify these cointegrating vectors, additional restrictions are imposed. The restrictions on the coefficients are the following: (1) the coefficients of RER and RGDP in the first cointegrating vector are equal to -1 and zero; (2) the coefficients of RGDP and RER in the second cointegration vector are equal to -1 and zero. The two additional tests fail to reject the null hypothesis (the results are not reported), which confirms that RGDP should not enter into the RER equation and RER should not be included in the growth equation.

2.5.3.4 Identifying the One Cointegrating Vector from the Max-eigenvalue Test

The maximum eigenvalue test indicates that only 1 cointegrating vector exists in the cointegration system. Figure 2.16 presents the cointegration relationship indicated by the maximum eigenvalue test. The X-form and R-form models are not widely different, which implies the stationary of the cointegrating vector.

To identify cointegrating vectors from the trace test, the recursive test of the eigenvalue and beta constancy has been introduced. In this section, the maximum eigenvalue test is only carried out in Eviews. The cointegration graph is represented in Figure 2.16, which supports the stationarity of the cointegrating vector. To further test the accuracy of the cointegrating vector, we impose two restrictions on the cointegrating vector to test the weak exogeneity of RGDP and FER. The Chi-square equals 0.21, which accepts the null hypothesis that RGDP and FER are weakly exogenous. Thus, RGDP and FER should not be included in the cointegrating vector. However, we still would like to further check the economic meaning of the cointegration relationship. The cointegrating vector is expressed as: $ecm1 = lnRER - 0.445 lnRGDP - 0.316 lnFER - 0.679 lnImp + 1.394 lnExp + 0.912 lnFDI - 3.814$. The normalised equation form is the following:

$$\begin{aligned} lnRER = & 3.814 + \underset{(1.601)}{0.445}\, lnRGDP + \underset{(1.089)}{0.316}\, lnFER + \underset{(2.156)}{0.679}\, lnImp \\ & - \underset{(3.219)}{1.394}\, lnExp - \underset{(5.56)}{0.912}\, lnFDI + \varepsilon \end{aligned} \tag{2.18}$$

The above equation gives the long run relationship between RER and its determinants. There is a positive correlation between RER and RGDP. It indicates that 1 % increase in RGDP will depreciate the Chinese currency by 0.445%. This contrasts against the historical statistics in Figure 2.1 and Figure 2.3, as they show that the exchange rate consecutively experiences appreciation and a stable growth rate is maintained in China since 1994. The cointegrating vector also reveals that foreign reserves and imports are positively correlated with RER. The elasticities are 0.316 and 0.679, respectively. This means that the increasingly accumulated FER and increasing of imports depreciate the Chinese currency. However, those figures (Figure 2.1, Figure 2.2 and Figure 2.4) just partially support this conclusion. Furthermore, the coefficients of RGDP and FER are not statistically significant at the 5% level. This further proves that both the RGDP and FER are weakly exogenous. Added to that, the cointegrating vector shows that exports and FDI have a negative impact on RER, and their elasticities are much larger compared with RGDP, FER and imports. This implies that exports and FDI have greater impact on RER than other variables. The coefficients for exports and FDI are -1.394 and -0.912, respectively, and they are also statistically significant at the 5% level. This means that increases in exports and FDI appreciates the RMB, which is what the trade partners want. Nevertheless, these findings go against the reality, since the increase in exports actually helps depreciate the Chinese currency.

In general, the cointegration relationship in equation (2.18) is completely different with equation (2.16) in terms of the sign and the magnitude of the coefficients. In addition, some coefficients (RGDP and FER) are not statistically significant and the economic meaning of the latter equation does not comply with the reality. The test of additional restrictions implies these variables are weakly exogenous. Concerning non-zero columns of the adjustment speed α, the weak exogeneity test of the cointegration rank indicates the adjustment speeds are equal to zero and the cointegrating vector in β is not stable. Besides the statistic inefficiencies of the cointegrating vector, recent reports show that China's growth slowed down compared with previous years. The increase in imports in China led to the appreciation of the RMB, whereas increases in exports and inflow of foreign capital boosted China's economy and depreciated the RMB. Based on these realities, the two cointegrating vectors in equation (2.16) and equation (2.17) are more likely to be accepted.

2.5.4 Identifying the Short Run Structure

The long run equilibrium between RER and Economic growth has been identified in the previous section. This chapter is also interested in examining the short run dynamics of the RER-growth relationship. This is carried out in the VECM. This chapter intends to revisit the structural change of the 2005 RMB exchange rate reform, which has been widely discussed in the existing literature. These studies artificially include the dummy in the regression model, so they could get plausible results. This chapter examines the breakpoint by checking the structural dummy both inside and outside of the VECM framework. The optimal lag length for the VECM is determined by the information criterion. When 2 lags are included in the system, both the AIC and BIC values are the smallest. The error correction models of the RER and RGDP equations are represented in Table 2.10. The two error correction terms (ecm_1 and ecm_2) are negative and statistically significant, which represent the speed of adjustment of the system returning to the long run equilibrium after a shock. The first error correction term indicates that the system corrects its previous level of disequilibrium by 1.9% within one month. Alternatively, 1.9% of RER changes will be corrected each month. The second error correction term of -0.007 means that 0.7% of disequilibrium in RGDP will be adjusted every month. In the table, most short run parameters are very small and non-significant. Further, the Wald tests of these regressors suggest that they are weakly exogenous and can be excluded from the model.

The lower part of Table 2.10 gives diagnostic tests of two equations. The normality of regression residuals is highly associated with the lag length selection of the VECM. When 11 lags are selected, regression residuals are normally distributed but the model suffers from severe autocorrelation and heteroskedasticity in residuals. When 2 lags are selected, there are no problems of autocorrelation and heteroskedasticity, but regression residuals are not normally distributed. Therefore, a parsimonious error correction model is estimated (2 lags are selected).

The coefficient of the dummy variable (D) is very small and negative but not statistically significant in the RER equation (see Table 2.10). The Wald test accepts the null hypothesis that the parameter is equal to zero. This means that the 2005 exchange rate regime reform did not impact on the stability of the Chinese currency. However, the dummy is significant in the RGDP equation and the Wald test demonstrates the non-rejection of the null hypothesis, which indicates that the 2005 RMB policy reform contributed to the economic growth in China in the short run.

To investigate the structural change of the 2005 RMB policy reform in the RER equation, both the Chow breakpoint test and the Quandt-Andrews unknown breakpoint test are carried out. Reestimating the VECM of the RER equation by excluding the dummy variable, the results almost the same as reported in Table 2.10.[37] Table 2.11 represents the structural break test for the 2005 RMB policy reform. Both the Chow break point test and the Quandt-Andrews test conclude that there are no breakpoints in 2005. Although the RMB policy changes are well known for an historical perspective, this chapter finds that it has no direct impact on the Chinese currency. However, the policy changes is found to be positively correlated with the RGDP in the short run according to the VECM estimates (see the $\Delta lnRGDP$ in the table).

Since the VECM estimates are parsimonious, the stability of the two equations can be examined by testing recursive residuals. If the residuals lie outside the standard error band, then this suggests the instability of estimated parameters. There are two types of recursive residuals, the cumulative sum of residuals (CUSUM) and the CUSUM of square test. The CUSUM test is built on the cumulative sum of the recursive residuals.[38] The option plots the cumulative sum together with the 5% significant lines. If the cumulative sum goes beyond the critical lines, the parameters are not stable. While the CUSUM of square test is based on the test statistic: $S_t = (\sum_{r=k+1}^{t} W_r^2)/(\sum_{r=k+1}^{T} W_r^2)$. The expected value S_t is under the hypothesis of parameter constancy: $E(S_{(t)} = (t-k)/(T-k))$, which goes from zero at $t = k$ to unity at $t = T$. The significance of the deviation of S_t from its expected value $E(S_t)$ is assessed by referencing the parallel straight lines around the expected value. Figure 2.17 represents the CUSUM test and cumulative sum of squares test. The upper and lower part of this figure present the recursive graph of $\Delta lnRER$ equation and $\Delta lnRGDP$ equation, respectively. For the $\Delta lnRER$ equation, the CUSUM test shows that the residuals are plotted within the 5% significance line, which indicates

[37] Both ways suggest that there are no structural changes. Since we are interested in the breakpoint test in the stability test, so the latter estimation is not reported.

[38] The CUSUM test is based on the statistic: $W_t = \sum_{r=k+1}^{T} W_r/s$, for $t = k+1, T$, where w is the recursive residuals and s is the standard deviation of the recursive residuals w_t. If the β vector remains constant from period to period, $E(w_t) = 0$. If β changes, W_t will diverge from the zero mean value line ,which suggests the instability of parameters.

the stability of the parameters. Nevertheless, the CUSUM of squares test shows that the variance of these parameters are not stable over the period 1997 to 2011, this could be due to the inclusion of weakly exogenous regressors. Another possible reason of the instable recursive residuals might be the parsimonious estimates of the VECM. However, the graphs of both the CUSUM and CUSUM of squares test are located within the 5% bands, which indicates the stability of the RGDP equation.

2.5.5 Impulse Response Analysis

The impulse response function clearly represents that the indicator responds to its spontaneous diffusion (disturbance), and other indicators respond to the disturbance in the same process, which could be positive, negative or continuous fluctuation in the response pattern, then return to normal. Figure 2.18 depicts the responses of the determinants after receiving a RER shock. RER responds to its own shock in a negative pattern. Basically, an increase in RER leads to the upturn of RGDP although there is a slight decline in the second stage. The increase in RER causes a continuous increase in FER across all periods. When the RMB depreciates, the Chinese authorities release the mass storage of foreign reserves to ease the depreciation speed of the Chinese currency. Meanwhile, the government tends to accelerate the accumulation of its FER in order to meet any severe lack of foreign reserves, which might cause uncertainties in the domestic economy and the regional economy. Moreover, the upturn of RER causes a slight decrease in imports and a slow increase in exports. This means that the RER shock does not demonstrate too much significant impact on foreign trade. This can be supported by the foreign trade in China in recent years, since the country is the largest exporter and the second largest importer in the world, although the RMB suffers continuous depreciation. Finally, the last impulse response shock depicted in Figure 2.18 shows that an increase in RER leads to a decline of foreign capital inflows in the short run, but the effect gradually weakens in the long run. All shock patterns corresponding to the disturbance of RER are consistent with the identified long run cointegrating vector in equation (2.16).

2.5.6 Test for Great Recession

The historical statistics indicate that the Chinese economy suffered recession during the 2008 global financial crisis. Global countries were seriously affected and experienced hard times in the domestic employment, foreign trade and financial stability. Comparatively, the Chinese economy recovered in a short period of time (within two years) maintaining the growth momentum, whereas other economies are still in the recession. Therefore, the linkages between RMB equilibrium exchange rate and economic growth after the great recession period are of interest to this chapter. To observe the impact of the great recession on China's economy and the RER-growth relationship, this section reestimates the RER equation over the sample period January 2008 to December 2012 applying the CVAR approach. To select the lag length for the cointegration system, the diagnostic test suggests that one lag is enough to remove the autocorrelation and heteroskedasticity in the regression residuals.

The test for the reduced rank is reported in Table 2.12. Both the trace test and the maximum eigenvalue test indicate that only one cointegrating vector exists in the cointegration system. The diagnostic tests do not show any signs of model instability. The cointegrating vector also does not exhibit any serious weak exogeneity. Furthermore, the cointegration relationship represented in Figure 2.19 tends to be more stationary than the long run equilibrium from the whole sample estimates (see Figure 2.8, 2.9 and 2.16). Both the X-form and R-form cointegration relationships mimic a white noise process. Although the Chinese economy was subjected to the recession in mid-2008, the relationship between RER and economic growth returns to the equilibrium within a short period. Since then, the cointegration relationship becomes quite stable as depicted in the figure.

The cointegrating vector is normalized in equation (2.19), which indicates that RGDP and FDI have a negative impact on RER, whereas other variables are positively correlated with RER. Compared with equation (2.16), the effect from exports has the same sign, but the effects from FER, imports and FDI are completely different in the two equations. The estimates from the whole sample period indicate that there is no direct correlation between RER and RGDP. While the great recession test represents that the increase in RGDP appreciates the RMB and the upturn of exports depreciates the RMB, respectively.[39] Speaking from a theoretical

[39] In equation (2.19), the significance of the coefficient of exports can be accepted at 10% level for a one-tailed test.

perspective, the currency of an economy is likely to appreciate if there has been a continuous growth. Foreign incomes flow in the economy with the expansion of exports, which leads to the currency depreciation. Nevertheless, the t-statistics for the coefficients of imports and exports are not statistically significant at the 10% level, which indicates the existence of possible weak exogeneity. The cointegrating vector is normalised into the following equation.

$$\begin{aligned} lnRER = & -1.539 - \underset{(-3.798)}{0.705}\, lnRGDP + \underset{(4.258)}{0.989}\, lnFER + \underset{(1.282)}{0.261}\, lnImp \\ & + \underset{(1.319)}{0.252}\, lnExp - \underset{(-8.325)}{1.196}\, lnFDI + \varepsilon \end{aligned} \tag{2.19}$$

In order to examine the weak exogeneity of imports and exports, additional restrictions are imposed in the test. The two restrictions test whether the coefficients of imports and exports are equal to zero. The Chi-square of the joint restriction test is 0.074, which accepts the null hypothesis that both the coefficients of exports and imports are equal to zero. When testing the two restrictions individually, the Chi-square is 0.356 (restriction on imports) and 0.441 (restriction on exports), which further proves that the two variables are weakly exogenous and could be excluded from the equation.

2.6 Discussion

Building upon the CVAR framework, this chapter has empirically explored the long run equilibrium and short run dynamics between RER and economic growth in China over the period January 1994 to December 2012. The identified long run relationship between RER and its determinants is represented in equation (2.16), which suggests that FER and imports have a negative impact on RER, whereas exports and FDI have a positive impact on RER. All these factors jointly maintain a stable Chinese currency. The large amount of foreign reserves in China is an effective tool for protecting the local currency from external shocks, but it appreciates the RMB in the long run. As presented by the RER equation, a 1% increase in foreign reserves leads to a decline (appreciation) of RER by 2.811%. It is known that FER is commonly used in international payments and to increase the supply of the USD in the foreign exchange market in case of the sharp depreciation of the RMB. However, the US economy gradually recovers after the great recession, the USD becomes stable and abundant in supply. To protect the RMB from appreciation, the Chinese authorities buy the USD and the US Treasuries (Morrison and Labonte, 2008), which further accelerates the accumulation of reserves in China. Meanwhile, the inflow of foreign products appreciate the Chinese currency. Having a cheaper labour force is the main reason of low purchase power of the RMB, but this could rise the national income by selling their products overseas. The increase in aggregate demand and people's willingness of purchasing foreign products becomes a driving force of RMB appreciation. Moreover, exports and FDI have a positive impact on the RER. The continuous expansion of exports increases foreign income, which benefits the labour-intensive industries in China, and concurrently prevents the currency from appreciation due to the increase in imports. Additionally, the peaceful political environment and good investment opportunities in China attract foreign investors. This causes the inflow of foreign capital and stimulates the development of local business, but it depreciates Chinese currency at the same time. In general, although the tradeoff between the appreciating and depreciating effects does not demonstrate too much discrepancies, we have to take into consideration the pressure from trade partners, since they are increasingly pressing the Chinese authorities to appreciate the RMB. Therefore, the effects on RMB appreciation outweigh the powers on RMB depreciation.

Since the RER always floats and fluctuates, the fluctuations observed in RER on the way towards long run equilibrium could be influenced by various sources: external shocks, expectations, policy changes, trade flows and so forth (Gylfason, 2002). As evidenced by a sample of 69 countries, the long run equilibrium RER is affected by macroeconomic fundamentals that are major source of causing RER misalignment, and the flexibility of the currency regime affects the degree of misalignment (Holtemöller and Mallick, 2013). In addition, De Broeck and Sløk (2006) find that exchange rate movements are also associated with productivity. Their interpretation of the productivity-driven RER changes reflects both the influences of structural transformation on productivity in tradable sections and the impact of changes in tradable sections against non-tradable sections in the productivity. The long run equilibrium exchange rate model varies in the literature, which is associated with three main sources of uncertainty (Égert et al., 2006): different theoretical underpinnings, different econometric methods, and different dimensions of datasets, ie, time series and cross sectional data. In the case of China, the long run RMB equilibrium exchange rate is achieved by the mutual interaction of foreign trade, foreign reserves and foreign direct investment. Since the authorities concern that the mainland Chinese financial system is not mature enough to handle the potential rapid cross-border movements of hot money, the currency trades within a narrow band specified by the PBOC. In the foreign exchange market, the yuan trends to be stable, but in goods market, exports and imports have been the major source of affecting currency movements. With the further opening to the outside world, the inflow of foreign capital also plays an important part in determining the RMB exchange rate. More and more investors invest in China as the Chinese market becomes more attractive. This adds another source of uncertainty to the RMB exchange rate. Therefore, the authorities have to stabilise the Chinese currency by buying foreign currencies in the foreign exchange market using foreign reserves. It has been the main tool for the authorities to manage currency market uncertainties.

In the growth equation, the long run relationship between RGDP and growth indicators is identified (see equation (2.17)). FER and imports are negatively correlated with RGDP, whereas exports and FDI are positively correlated with growth. Historical trade statistics show that China's trade surplus appeared since China joined the WTO in 2001 (see Figure 2.4). Concerning the foreign trade structure, China mainly imports high-tech equipments, minerals and electronics, but the imports of common products are still maintained at a moderate level. China's exports consist of most labour-intensive products, including most light industry products, mechanical equipments, home appliances, building materials, etc. Added to that, the Chinese official strives to reach trade agreements with foreign countries in bilateral or multilateral negotiations. These further support the fact that China currently has export-driven growth and the labour-intensive products are increasingly needed to expand their global markets. Meanwhile, the large population and potential consumer market in China stimulate the increase in imports. which might lead to a negative effect on growth.

In order to explore the short run dynamics of the RER-growth relation, a parsimonious error correction model is estimated (see Table 2.10). Exports are positively correlated with RER in the short run while other factors are found to be weakly exogenous according to the Wald test. The coefficients of two error correction terms are very small but statistically significant, which might be due to the parsimonious VECM and external disturbances, such as government intervention, market speculation and global crisis. The test for the effect of the 2005 RMB policy reform shows that the currency policy change does not have a significant impact on RER. A possible reason for this could be due to the managed floating exchange rate system, since the Chinese official has restrictions on the daily floating range of the RMB exchange rate. Furthermore, the policy dummy is statistically significant in the RGDP equation, which means that the currency policy reform has a small but positive impact on growth. This is consistent with previous findings that the exchange rate regime does have important impact on economic growth (Levy-Yeyati and Sturzenegger, 2003; Harms and Kretschmann, 2009; Tarawalie, 2011; De Vita and Kyaw, 2011).

This chapter further tests the nexus between RER and economic growth after the 2008 world financial crisis. Only one cointegration relationship is identified based on the sample of post-crisis period, which represents that RGDP and FDI have a negative impact on RER, while other variables have a positive impact on RER. Nevertheless, imports and exports are weakly exogenous in the identified cointegrating vector, which implies that foreign trade does not show any significant impact on RER after the crisis. This could be supported by the recent evidence that China's exports to the US and Europe are slowing down. But the Chinese government are proactively exploring other channels to expand exports, such as signing bilateral or multilateral trade agreements with emerging economies.

Concerning structural breaks in the empirical model,[40] this chapter tests the structural break of the 2005 RMB policy by incorporating a dummy variable in the model. The evidence from the Chow breakpoint test and the Quandt-Andrews unknown breakpoint test (see Table 2.11) shows that there are no structural breaks. The policy reform did not impact on RER but instead contributed to China's growth. As the recursive estimates indicate the existence of structural breaks in 2008, this chapter reestimates the CVAR model using the subsample of great recession period, which suggests that there is one cointegration relationship, see Figure 2.19.[41] It reveals that the Chinese currency is becoming more flexible and less dependent on foreign trade.

[40]There are two possible structural breaks in this model as shown in the data and cointegration relationships. One is the Chinese currency policy reform in 2005 and another one is the great recession period.

[41]In contrast, there are two cointegration vectors from the whole sample test.

2.7 Conclusions

This chapter has investigated the long run equilibrium and short run dynamics between RER and economic growth in China applying a CVAR approach. Two cointegrating vectors are identified in the cointegration system. The RER equation and RGDP equation address the puzzle of what maintains a stable Chinese currency and what drives the Chinese economy. Further, the structural change of the 2005 RMB policy reform and the RER-growth relationship after the great recession have been examined in this chapter. In response to the research questions, this section gives the conclusion in order as follows.

The cointegration test suggests that the Chinese economy has not benefited from the depreciation of the RMB. On the contrary, the RMB has been appreciating since early 1994, when the PBOC implemented the exchange rate policy reform. The exchange rate of USD/RMB appreciated almost by 38% by the end of 2012. In the long run, both exports and FDI have a positive impact on RER, whereas FER and imports have a negative impact on RER. These factors jointly determine the long run equilibrium of the RMB exchange rate. Meanwhile, exports and FDI have a positive impact on China's growth, and FER and imports are negatively correlated with RGDP. It is no doubt that foreign trade plays an important part in rejuvenating the Chinese economy. After China joined the WTO in 2001, foreign trade has been experiencing a dramatic growth. The identified RGDP equation also indicates that exports and FDI have a positive impact on economic growth, but imports do not contribute to growth. This is in accordance with the results from Yu (1998), who finds that imports have no significant contribution to economic performance. Added to that, there is no direct correlation between RER and RGDP in the long run. These empirical findings together with the historical evidence further confirm that the Chinese economy has benefited from the expansion of exports and the inflow of foreign capital.

In order to observe the short run dynamics between RER and economic growth, a VECM is carried out in the chapter in which structural changes of the 2005 RMB policy reform are examined. Both the short run dynamics analysis and breakpoint tests (the Chow breakpoint test and the Quandt-Andrews breakpoint test) indicate that there were no structural changes in the 2005 RMB policy reform. This is consistent with evidence from the existing literature (Shah et al., 2005; Zhiwen, 2011). In addition, the coefficient for the policy dummy in the RGDP equation is positive and statistically significant, which means that the RMB policy reform has a positive impact on China's growth in the short run. While the dummy variable is not significant in the RER equation, which suggests that the currency policy reform in China has no significant impact on the RER equilibrium exchange rate. This could be due to the government's different ways of managing the RMB exchange rate. Beside the restrictions on the currency's daily trading band, the China authorities flexibly apply different tools to maintain the stability of the Chinese currency, such as buying and selling the US treasuries using foreign reserves.

To stabilize domestic prices and keep the growth speed, China implements an ongoing managed floating exchange rate. However, the government intervention in the foreign exchange market is declining in recent years due to the economic globalisation and the increasing pressure from trade partners. In 2012, the daily floating range of USD to RMB was extended to 1%. With the maturity of the Chinese financial market and the internationalisation of the Chinese currency, it is hoped that the RMB will be tradeable in the foreign exchange market in the near future.

In addition, the great recession test reveals that the RER has not been significantly affected by foreign trade after 2008. Before the recession, the Chinese currency is jointly determined by the FER, foreign trade and FDI. After that, the RMB gradually becomes stable and flexible, which is mainly affected by the national strength, FER and inflow of foreign capital.

To conclude, several policy implications can be drawn from these empirical findings. In response to the continuous pressure from trade partners, the Chinese authorities may insist on the managed floating exchange rate system making appropriate adjustments to the daily floating range of the RMB exchange rate. Apart from this, the large amount of FER can be flexibly used in the global financial market to protect the Chinese currency from instability. In addition, with the disappearance of the advantage in exporting labour-intensive products due to the shift of global division (Ba and Shen, 2010), China should upgrade the existing export structure and focus on the development of capital and technical intensive products in the long run. This will not only contribute to growth, but also maintains the stability of the Chinese currency. It appears that the advantage of foreign trade in China is gradually diminishing according to the great recession test. Recent evidence also shows that China's exports to the US and Europe are slowing down. To keep the growth momentum and currency stability, it does not mean that China has to shift its exports to domestic consumption, but instead China can rebalance its economy by exporting to BRICS countries, emerging economics and other developing economies, especially exporting the infrastructures they need. Finally, it is evident that there are plenty of pollution problems in China, which are concerned by the general public and the international community, therefore, increasing domestic investment could also be an effective way for rebalancing the Chinese economy.

Table 2.1: Data sources and variables definition

Variable	Definition and Data Source	Unit
NER	Norminal exchange rate of USD/RMB	Index
	Source: People's Bank of China	
GDP	Gross Domestic Product of China	Billion
	Source: National Bureau of Statistics of China	
CPI	Consumer Price Index of China	Index
	Source: National Bureau of Statistics of China	
FER	Foreign Exchange Reserves	Billion USD
	Source: State Administration of Foreign Exchange	
Exp	Exports of China	Billion USD
	Source: General Administration of Customs of China	Billion USD
Imp	Imports of China	Billion USD
	Source: General Administration of Customs of China	Billion USD
FDI	Actual usage of Foreign Direct Investment of China	Index
	Source: Invest in China	
D	Dummy variable	Index
	if $t >$ July 2005, D=1, otherwise, D=0	Index

Note: The US CPI is not listed in the table, which can be obtained from the IMF. It is used for adjusting the RER in this chapter.

Table 2.2: Summary statistics and correlation matrix

	lnRER	lnRGDP	lnFER	lnExp	lnImp	lnFDI
Mean	2.150	6.072	6.033	3.686	3.547	3.891
Median	2.183	5.940	5.862	3.572	3.533	3.858
Std.Dev.	0.239	0.983	1.390	0.962	0.955	0.419
Skewness	0.148	0.027	0.025	0.083	0.089	0.224
Kurtosis	2.355	2.094	1.765	1.517	1.542	2.106
Jarque-Bera	4.781	7.825	14.501	21.138	20.504	9.506
P-value	0.092	0.020	0.000	0.000	0.000	0.009
Obs.	228	228	228	228	228	228
lnRER	1.000					
lnRGDP	-0.989	1.000				
lnFER	-0.976	0.992	1.000			
lnExp	-0.942	0.972	0.989	1.000		
lnImp	-0.934	0.967	0.981	0.995	1.000	
lnFDI	-0.873	0.893	0.894	0.886	0.888	1.000

Table 2.3: Unit root tests (ADF and KPSS tests)

Variable	Level		1st Difference	
	ADF	KPSS	ADF	KPSS
constant only				
lnRER	-2.169(0)	1.874(11)***	-14.276(0)***	0.304(5)
lnRGDP	-1.681(0)	1.945(11)***	-14.580(0)***	0.324(7)
lnFER	-1.529(3)	1.990(11)***	-4.374(2)***	0.392(10)
lnExp	-0.615(2)	1.996(11)***	-15.268(1)***	0.101(7)
lnImp	-0.418(1)	1.990(11)***	-26.297(0)***	0.050(7)
lnFDI	-1.715(2)	1.835(11)***	-12.814(2)***	0.014 (1)
constant and trend				
lnRER	-1.564(0)	0.143(11)*	-14.500(0)***	0.122(4)*
lnRGDP	-2.301(0)	0.170(11)**	-14.700(0)***	0.272(7)***
lnFER	-1.894(3)	0.176(11)**	-4.559(2)***	0.191(10)
lnExp	-1.623(2)	0.216(11)**	-15.235(1)***	0.072(7)
lnImp	-2.662(1)	0.208(11)**	-26.236(0)***	0.048(7)
lnFDI	-6.255(1)***	0.282(11)***	-12.783(2)***	0.010 (1)

Critical value	constant only			constant and trend		
	1%	5%	10%	1%	5%	10%
ADF	-3.459	-2.874	-2.573	-3.999	-3.429	-3.138
KPSS	0.739	0.463	0.347	0.216	0.146	0.119

Notes:

1. ***, ** and * means the rejection of the null hypothesis at the 1% , 5% and 10% levels.
2. Each test is carried out by imposing the restrictions of a constant, and both constant and trend, respectively.
3. Numbers in parentheses are optimal lags. Bayesian information criterion (BIC) and Newey-West Bandwidth selection criterion are selected for the ADF test and for KPSS test, respectively.

Table 2.4: Unit root test (Ng-Perron test)

Variable	Level				1st Difference			
	MZ_{α}^{GLS}	MZ_{t}^{GLS}	MSB^{GLS}	MP_{T}^{GLS}	MZ_{α}^{GLS}	MZ_{t}^{GLS}	MSB^{GLS}	MP_{T}^{GLS}
Include a constant only								
lnRER	0.817(8)	0.949(8)	1.161(8)***	88.344(8)***	-6.321(7)*	-1.750(7)*	0.277(7)***	3.971(7)***
lnRGDP	1.288(8)	1.526(8)	1.185(8)***	101.005(8)***	-1.982(7)	-0.962(7)	0.485(7) ***	12.005(7)***
lnFER	1.242(9)	2.546 (9)**	2.049(9)***	285.413(9)***	-9.985(8)**	-2.165(8)**	0.216(8)***	2.764(8)***
lnExp	1.373(6)	3.011(6)***	2.194(6)***	334.943(6)***	-0.179(5)	-0.204(5)	1.136 (5)***	66.952(5) ***
lnImp	1.388(1)	2.576(1) **	1.856(1)***	241.461(1)***	-15.884(0)*	-2.781(0)*	0.175(0)***	1.683(0)
lnFDI	0.573(12)	0.464(12)	0.811(12)***	44.419(12)***	-94.0 (0)***	-6.857(0)***	0.073(0)	0.261(0)
Include both the constant and trend								
lnRER	-2.001(0)	-0.804(0)	0.402(0)***	34.505(0)***	-2.168(13)	-1.013(13)	0.467(13)***	40.548(13)***
lnRGDP	-3.322(6)	-1.284(6)	0.386(6)***	27.332(6)***	-3.632(7)	-1.327(7)	0.365(7)***	24.769(7)***
lnFER	-4.454(3)	-1.336(3)	0.299(3)***	19.260(3)***	-1.529(8)	-0.841(8)	0.550(8)***	56.209(8)***
lnExp	-4.089(2)	1.370(2)	0.335(2)***	21.642(2)***	-0.611(5)	-0.397(5)	0.650 (5)***	84.003(5)***
lnImp	-8.840(2)	-2.079(2)	0.235(2)***	10.397(2)***	0.431(9)	-0.398(9)	0.922(9)***	158.839(5)***
lnFDI	-2.753(13)	-1.170(13)	0.425(13)***	32.995(13)***	-93.390(0)***	-6.833(0)***	0.073(0)	0.978(0)
Critical Value (Constant only)	1%	5%	10%	Critical Value (Constant and trend)	1%	5%	10%	
MZ_{α}^{GLS}	-13.8	-8.1	-5.7		-23.80	-17.30	-14.20	
MZ_{t}^{GLS}	-2.58	-1.98	-1.62		-3.42	-2.91	-2.62	
MSB^{GLS}	0.174	0.233	0.275		0.143	0.168	0.185	
MP_{T}^{GLS}	1.78	3.17	4.45		4.03	5.48	6.67	

Notes:

1. ***,** and * indicate the rejection of the null hypothesis at the 1%, 5% and 10% levels, respectively.
2. Each test is carried out by imposing the restrictions of a constant and both constant and trend, respectively.
3. Numbers in parentheses are optimal lags, which is selected by the modified Akaike information criterion (M-AIC).

Table 2.5: Summary of unit root tests

Variable/Tests	ADF	KPSS	Ng-Perron
Include a constant only			
lnRER	I(1)	I(1)	I(1)
lnRGDP	I(1)	I(1)	NA
lnFER	I(1)	I(1)	I(1)
lnExp	I(1)	I(1)	NA
lnImp	I(1)	I(1)	NA
lnFDI	I(1)	I(1)	NA
Include both the constant and trend			
lnRER	I(1)	I(1)	NA
lnRGDP	I(1)	I(1)	NA
lnFER	I(1)	I(1)	NA
lnExp	I(1)	I(1)	NA
lnImp	I(1)	I(1)	NA
lnFDI	I(0)	I(1)	NA

Notes:

1. The summary of stationary tests is based on Table 2.3 and Table 2.4.
2. NA denotes that the unit root test cannot give a specific conclusion of integration order. The M-test statistic cannot fully reject the null hypothesis both in levels and first differences.

Table 2.6: Multivariate unit root test (Johansen test)

K	$H_0^*(r)$	$H_1(r)$	$H_{1.1}(r)$	$H_1^*(r)$	$H_2(r)$
2	2.214	0.216	0.005	1.665	1.489
3	2.610	0.118	0.256	1.485	1.454
4	2.587	0.071	0.180	1.934	1.903
5	3.581	0.612	0.348	2.220	2.201
6	3.124	0.164	0.001	2.368	2.018
7	3.680	0.305	0.418	3.827	1.733
8	2.357	0.015	0.525	2.329	1.262
5% critical Value	12.518	3.841	3.841	9.165	4.130

Notes:

1. K is the lag length for the Johansen test, and two lags are initially selected for the test .
2. Critical values are from the paper of Johansen and Juselius (1994).
3. $H_0^*(r)$ denotes the restriction of liner constant and trend.
4. $H_1(r)$ denotes the restriction of liner constant and quadratic trend.
5. $H_{1.1}(r)$ denotes the restriction of liner constant and no trend.
6. $H_1^*(r)$ denotes the restriction of no-restricted constant and no trend.
7. $H_2(r)$ denotes the restriction of no constant and no trend.

Table 2.7: Trace test for cointegration rank

Hypothesized No. of CE(s)	Eigenvalue	Trace statistic	0.05 Critical Value	P-value **
0	0.225	134.221	95.754	0.000*
1	0.130	76.872	69.819	0.012*
2	0.124	45.491	47.856	0.082
3	0.056	15.784	29.797	0.727
4	0.013	2.897	15.495	0.971
5	0.000	0.005	3.841	0.945

Notes:

1. The trace test indicates the existence of 2 cointegrating equations at the 5% level.
2. * denotes the rejection of the hypothesis at the 5% level.
3. **denotes the Mackinnon et al. (1999) p-values.

Table 2.8: Maximum eigenvalue test for cointegration rank

Hypothesized No. of CE(s)	Eigenvalue	λ_{max} statistic	0.05 Critical Value	P-value **
0	0.225	57.349	40.078	0.000*
1	0.130	31.381	33.877	0.097
2	0.124	29.707	27.584	0.026
3	0.056	12.888	21.132	0.463
4	0.013	2.892	14.265	0.954
5	0.000	0.005	3.841	0.945

Notes:

1. The max-eigenvalue test indicates the existence of 1 cointegrating equation at the 5% level.
2. * denotes rejection of the hypothesis at the 5% level.
3. **denotes the Mackinnon et al. (1999) p-values.

Table 2.9: Modulus of six largest roots

r=1	r=2	r=3	r=4	r=5	r=6
1.000	1.000	1.000	1.000	1.000	1.007
1.000	1.000	1.000	1.000	0.981 (-0.044)	0.980 (-0.046)
1.000	1.000	1.000	0.971 (0.000)	0.881 (-0.044)	0.880 (-0.046)
1.000	1.000	0.967 (0.000)	0.815 (0.000)	0.808 (0.000)	0.802 (0.000)
1.000	0.975 (0.000)	0.823 (0.000)	0.809 (0.000)	0.769 (0.000)	0.769 (0.000)
0.892 (0.000)	0.532 (0.000)	0.532 (0.000)	0.533 (0.000)	0.532 (0.000)	0.533 (0.000)

Note: P-values are reported in parentheses.

Table 2.10: A parsimonious VECM estimates of $\Delta lnRER$ and $\Delta lnRGDP$

Regressor	$\Delta lnRER$		$\Delta lnRGDP$	
	Coefficient (P-value)	Wald test (P-value)	Coefficient (P-value)	Wald test (P-value)
Intercept	-0.059(0.021)	$\chi^2_{(1)}$=5.445(0.020)	-0.168(0.000)	$\chi^2_{(1)}$=18.486(0.000)
$\Delta lnRER$(-1)	0.111 (0.261)	$\chi^2_{(1)}$=1.270(0.260)	0.051(0.736)	$\chi^2_{(1)}$=0.114(0.735)
$\Delta lnRER$(-2)	0.126(0.196)	$\chi^2_{(1)}$=1.680(0.195)	-0.373(0.013)	$\chi^2_{(1)}$=6.222(0.013)
$\Delta lnRGDP$(-1)	0.102(0.103)	$\chi^2_{(1)}$=2.685(0.101)	-0.031(0.748)	$\chi^2_{(1)}$=0.103(0.748)
$\Delta lnRGDP$(-2)	0.071(0.252)	$\chi^2_{(1)}$=1.319(0.251)	-0.181(0.059)	$\chi^2_{(1)}$=3.612(0.057)
$\Delta lnFER$(-1)	-0.008(0.868)	$\chi^2_{(1)}$=0.028(0.868)	-0.132(0.088)	$\chi^2_{(1)}$=2.931(0.087)
$\Delta lnFER$(-2)	-0.40(0.433)	$\chi^2_{(1)}$=0.618(0.432)	0.065(0.405)	$\chi^2_{(1)}$=0.697(0.404)
$\Delta lnExp$(-1)	0.037(0.031)	$\chi^2_{(1)}$2=4.730(0.030)	-0.048(0.068)	$\chi^2_{(1)}$=3.365(0.067)
$\Delta lnExp$(-2)	0.033(0.031)	$\chi^2_{(1)}$=4.703(0.030)	-0.021(0.364)	$\chi^2_{(1)}$=0.827(0.363)
$\Delta lnImp$(-1)	-0.022(0.088)	$\chi^2_{(1)}$=2.929(0.087)	0.027(0.173)	$\chi^2_{(1)}$=1.870(0.171)
$\Delta lnImp$(-2)	-0.015(0.187)	$\chi^2_{(1)}$=1.754(0.185)	0.025(0.142)	$\chi^2_{(1)}$=2.170(0.141)
$\Delta lnFDI$(-1)	0.009(0.131)	$\chi^2_{(1)}$=2.303(0.129)	-0.010(0.245)	$\chi^2_{(1)}$=1.360(0.244)
$\Delta lnFDI$(-2)	0.005(0.249)	$\chi^2_{(1)}$=1.335(0.248)	-0.008(0.294)	$\chi^2_{(1)}$=1.109(0.292)
D	-0.002(0.458)	$\chi^2_{(1)}$=0.417(0.519)	0.008(0.012)	$\chi^2_{(1)}$=6.379(0.012)
$ecm_1(-1)$	-0.019(0.083)	$\chi^2_{(1)}$=3.031(0.082)	0.065(0.000)	$\chi^2_{(1)}$=14.340(0.000)
$ecm_2(-1)$	0.007(0.009)	$\chi^2_{(1)}$=6.993(0.008)	-0.019(0.012)	$\chi^2_{(1)}$=23.247(0.000)
R- squared	0.114		0.190	
DW-statistic	2.029		2.003	
S.E. of Regression	0.011		0.017	
LM test	$\chi^2_{(2)}$=2.365(0.307)		$\chi^2_{(2)}$=0.662(0.718)	
ARCH effect	$\chi^2_{(2)}$=0.446(0.800)		$\chi^2_{(2)}$=0.412(0.521)	

Table 2.11: Structural breaks test for the 2005 RMB policy reform

Test	Statistic (P-value)
Chow breakpoint test for the exchange rate regime reform in July 2005	
F-statistic	1.174(0.295)
Log likelihood radio	$\chi^2_{(14)}$=19.456 (0.194)
Wald statistic	$\chi^2_{(2)}$= 17.612 (0.284)
Quandt-Andrews unknown breakpoint test with 30% trimming (1999:12-2007:05)	
Maximum LR F-statistic (2000:03)	1.335(0.621)
Maximum Wald F-statistic (2000:03)	20.036(0.621)
Exp LR F-statistic	0.540 (0.552)
Exp Wald F-statistic	8.841 (0.434)
Ave LR F-statistic	1.068 (0.361)
Ave Wald F-statistic	16.022(0.361)

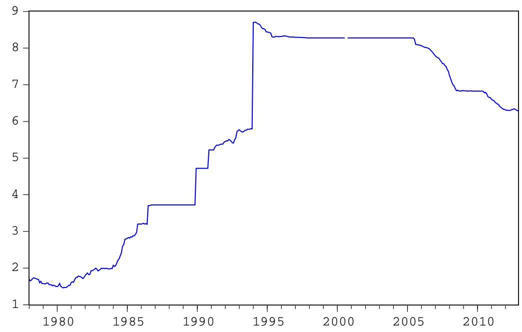
Table 2.12: Cointegration test for the great recession

$H_0 r$	$n-r$	Eigenvalue	$-Tlog(1-\hat{\lambda}_r)$	$\lambda_{trace}(0.95)$	$-Tlog(1-\hat{\lambda}_{r+1})$	$\lambda_{max}(0.95)$
0	6	0.627	124.810**	95.754	57.217**	40.078
1	5	0.403	67.593	69.819	29.946	33.877
2	4	0.303	37.647	47.856	20.918	27.584
3	3	0.157	16.729	29.797	9.895	21.132
4	2	0.107	6.834	15.495	6.559	14.265
5	1	0.005	0.275	3.841	0.275	3.841

Notes:

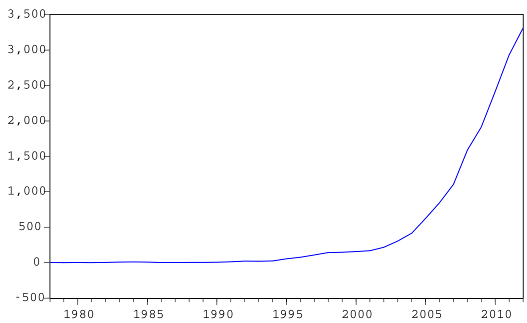
1. The sample for the great recession test ranges from January 2008 to December 2012.
2. ** denotes the rejection of the null hypothesis at the 5% level.

Figure 2.1: Nominal exchange rate of USD/RMB



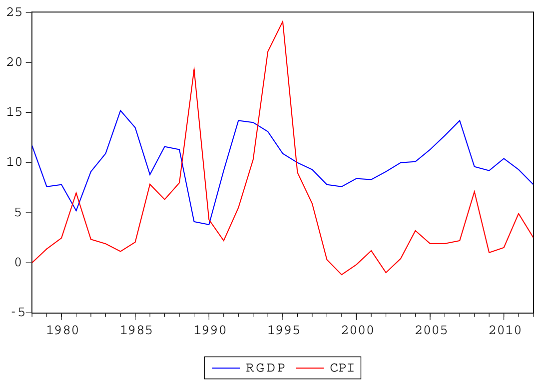
Source: State Administration of Foreign Exchange (1978-2012) (Billions USD)

Figure 2.2: Foreign exchange reserves (FER)



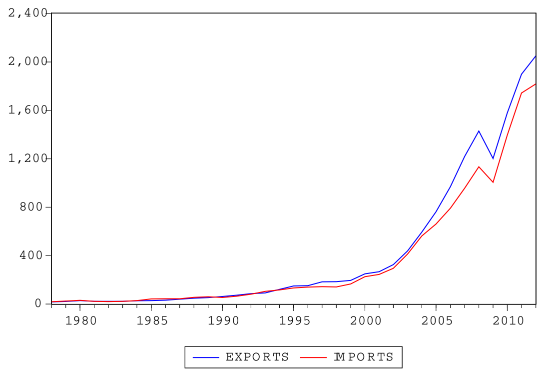
Source: State Administration of Foreign Exchange (1978-2012) (Billions USD)

Figure 2.3: GDP and CPI growth rates



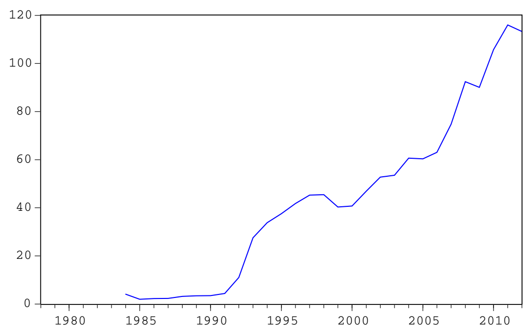
Source: National Bureau of Statistics of China (1978-2012)

Figure 2.4: Exports and imports



Source: General Administration of Customs of the People's Republic of China (Billions USD)

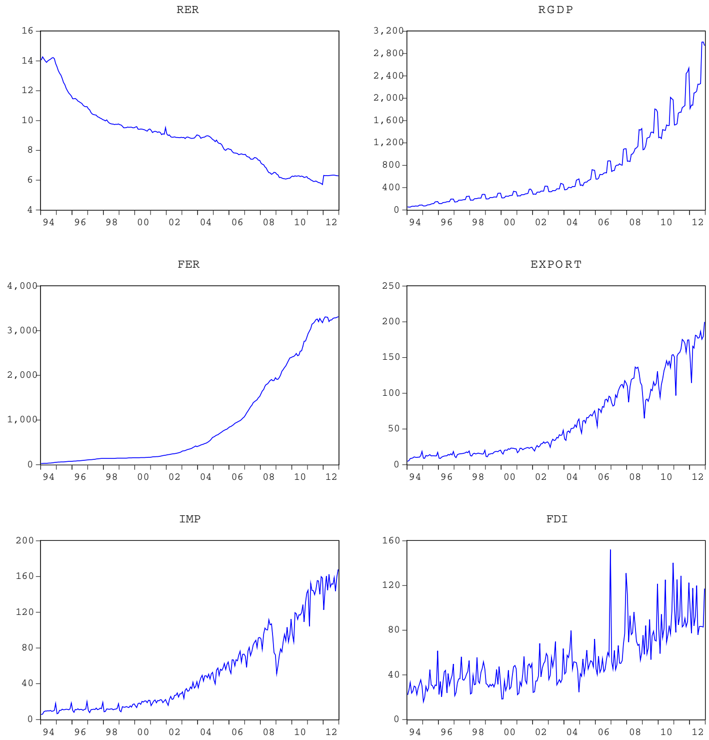
Figure 2.5: Foreign direct investment (FDI)



Source: The Ministry of Commerce of the People's Republic of China.(1978-2012) (Billions USD)

Figure 2.6: Plots of original series

(RER, RGDP, FER, Exp, Imp and FDI, 1994:01-2012:12)



Continued plots of the logarithmic forms of seasonally adjusted series:
(lnRER, lnRGDP, lnFER, lnExp, lnImp and lnFDI, 1994:01-2012:12)

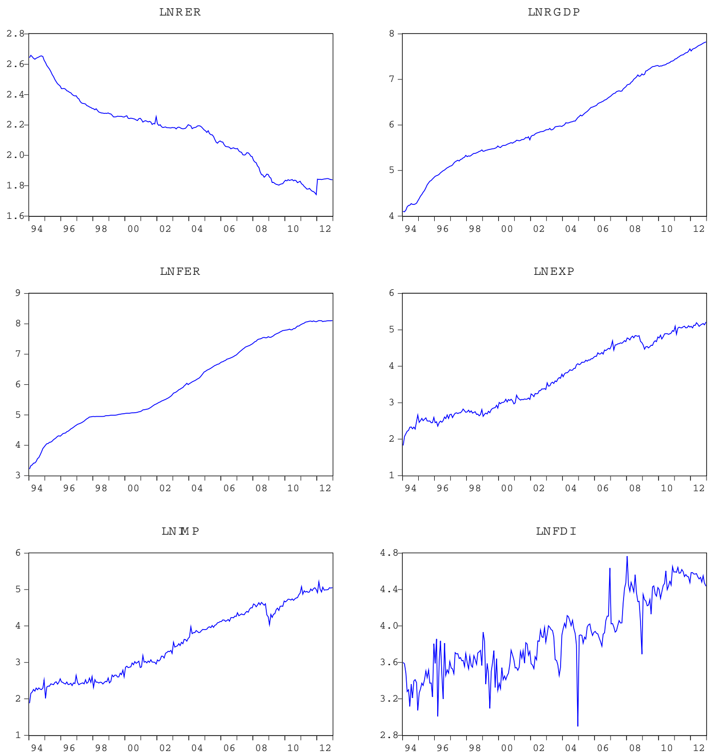


Figure 2.7: Plots of first-differenced series

(DlnRER, DlnRGDP, DlnFER, DlnExp, DlnImp and DlnFDI, 1994:01-2012:12)

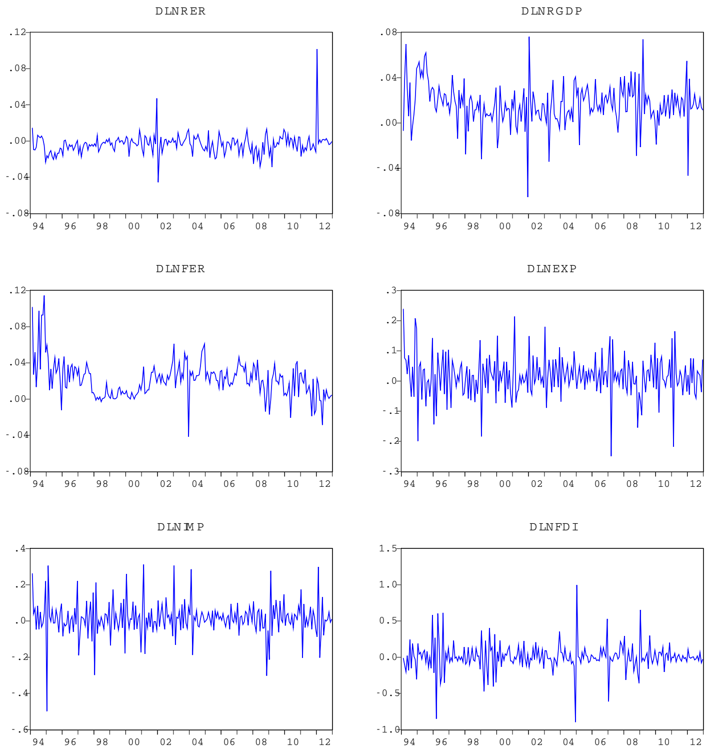
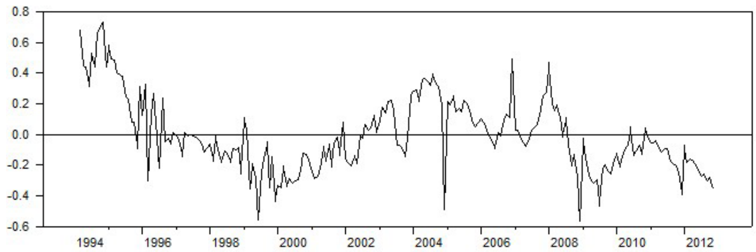
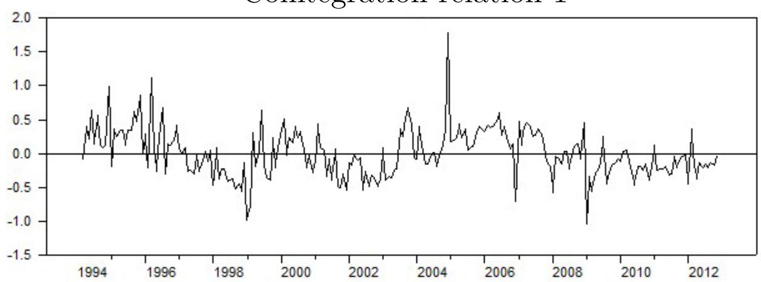


Figure 2.8: Cointegration relationships (trace test, $\hat{\beta}_1' x_t$)



— Cointegration relation 1



— Cointegration relation 2

Figure 2.9: Cointegration relationships (trace test, $\hat{\beta}_1' \hat{R}_{kt}$)

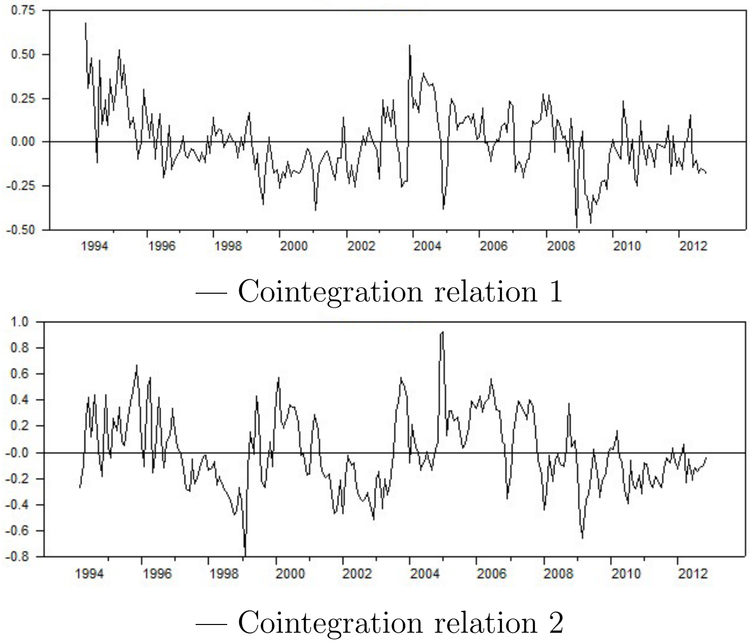


Figure 2.10: The recursive trace test statistic

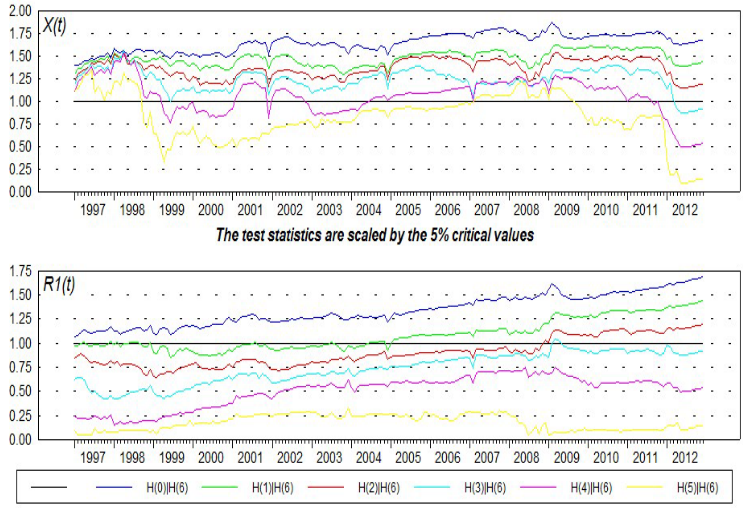


Figure 2.11: Recursively calculated eigenvalues

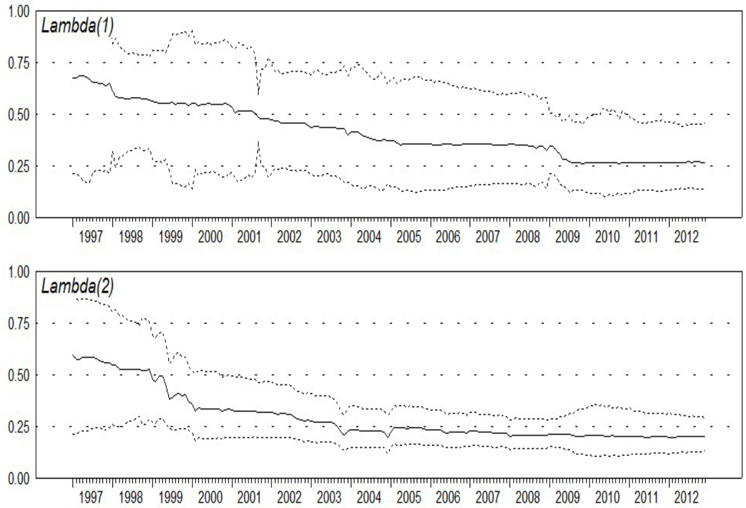


Figure 2.12: Recursively calculated log transformed eigenvalues

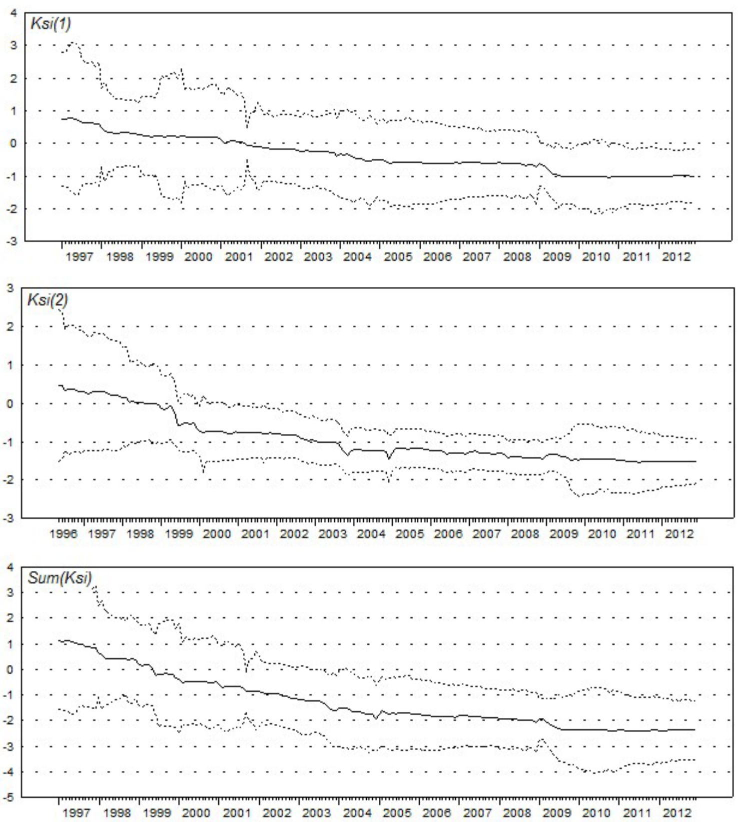


Figure 2.13: Eigenvalue fluctuation test

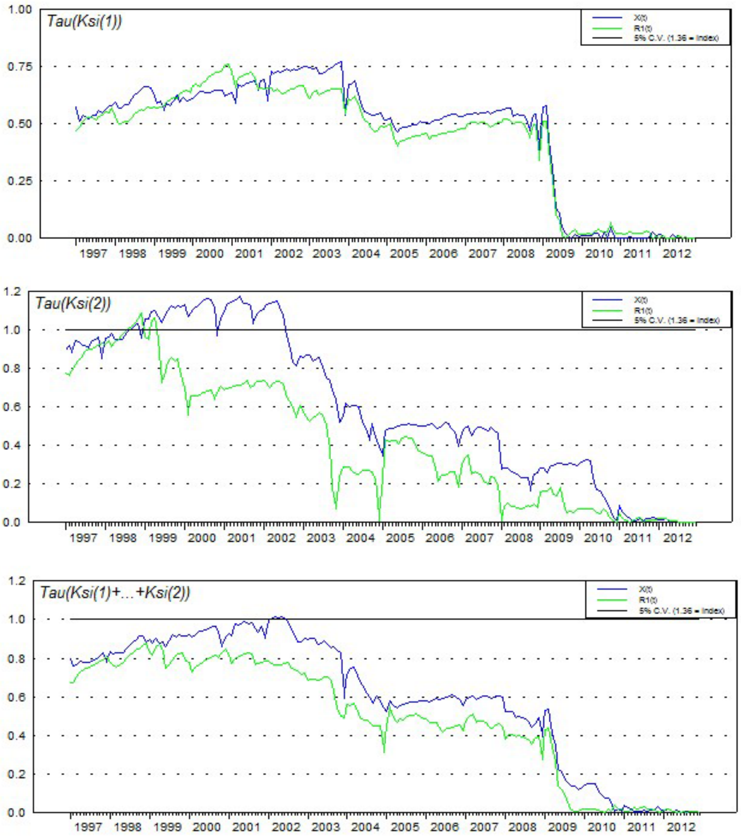


Figure 2.14: The max test of β constancy

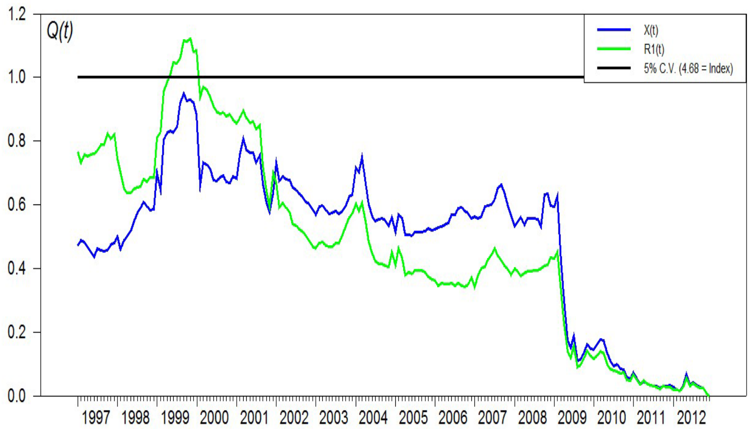


Figure 2.15: Test of β_t="known beta"

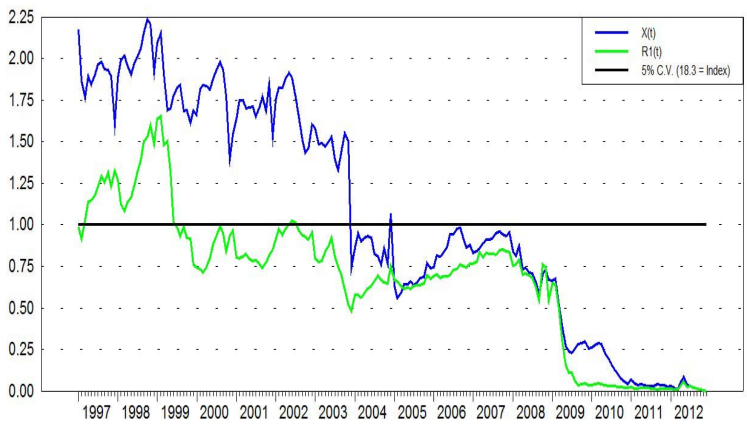


Figure 2.16: Cointegration relationship (λ_{max} test)

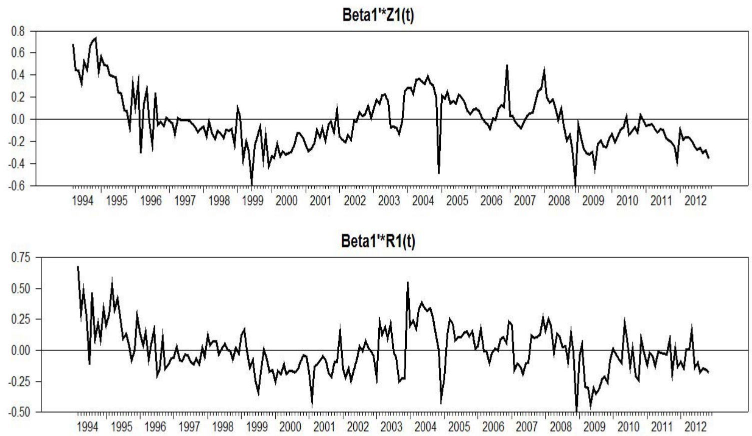
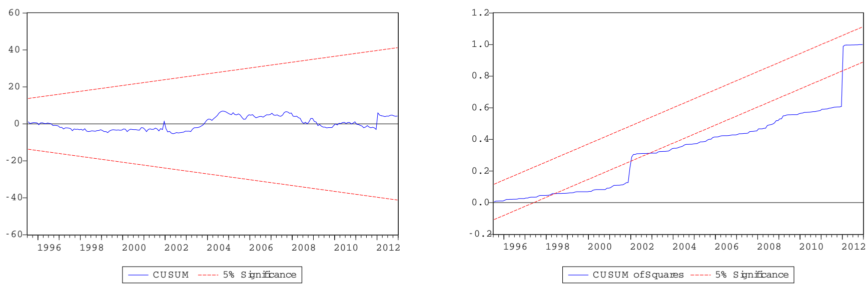
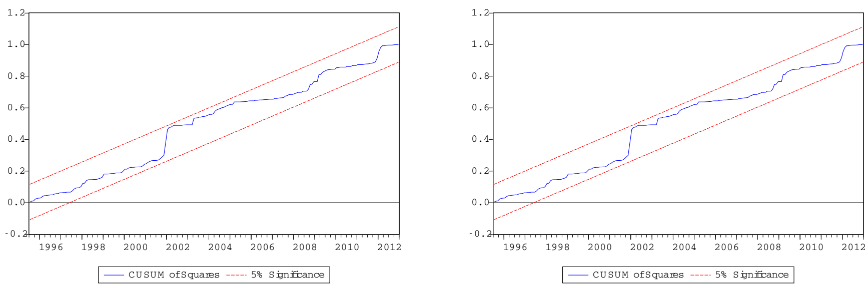


Figure 2.17: CUSUM and CUSUM of square test



$\Delta lnRER$ equation



$\Delta lnRGDP$ equation

Figure 2.18: Response of lnRER to Cholesky one S.D. innovations

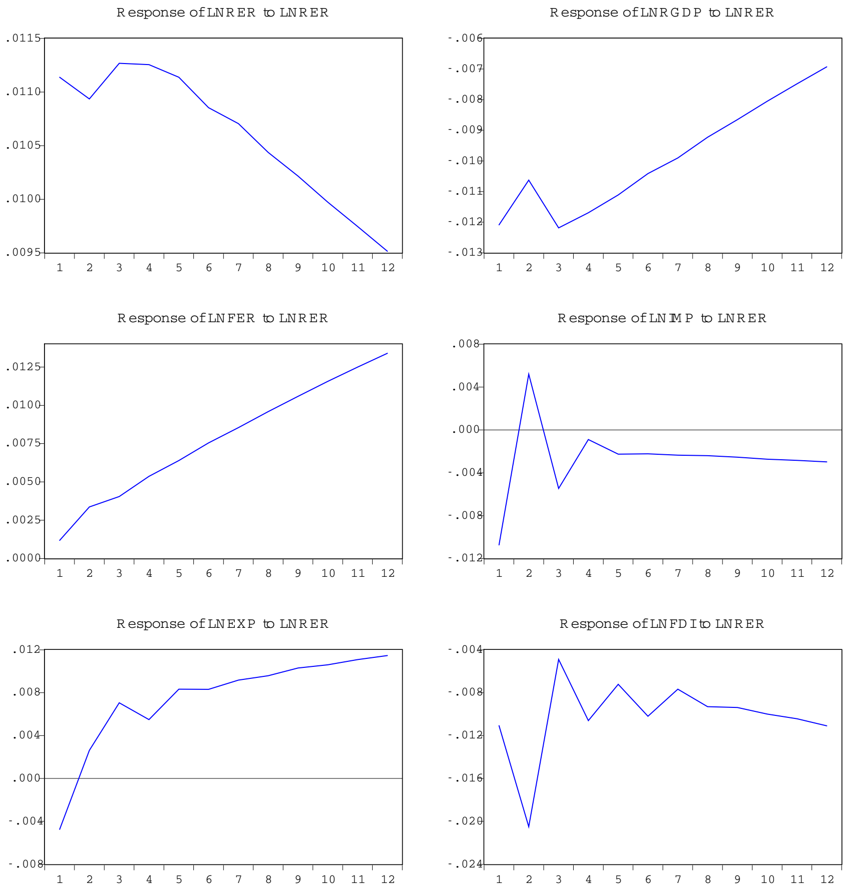
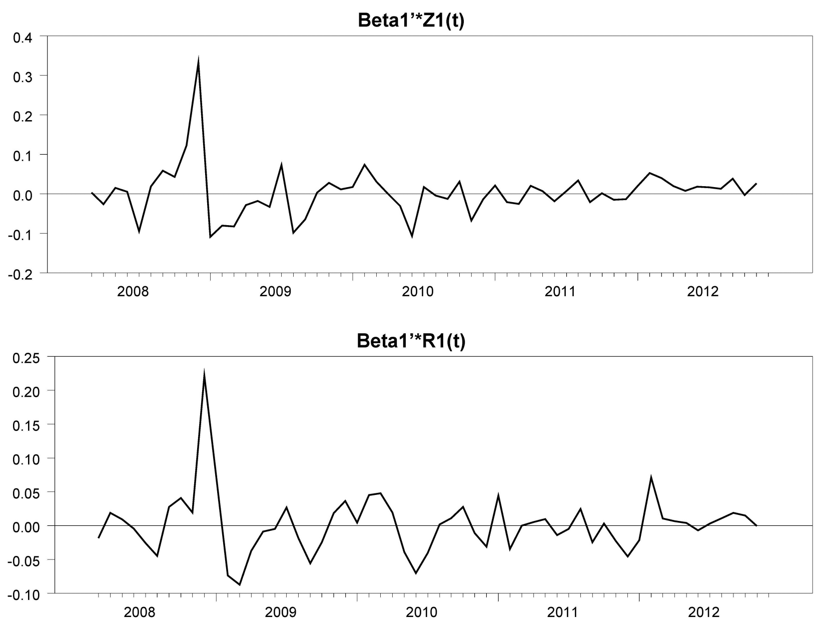


Figure 2.19: Cointegration relationship from the great recession test



Chapter 3

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

3.1 Introduction

The lesson from past financial crises indicates that currency shocks have devastating spillover effects on stock markets, and the regional and global economy, which were strongly demonstrated by the 1997 Asian financial crisis and the 2008 world financial crisis. The Asian financial crisis started in Thailand with the collapse of the Thai currency in July 1997. Most of Southeast Asia saw slumping currencies and stock prices as the crisis spread. However, China not only received fewer shocks from the crisis, but also helped to combat the crisis. China's main contribution to the transition and stabilisation of the Asian financial crisis came in not devaluing its currency, which gave a guarantee to the international community and maintained stability in the region. Apart from Hong Kong, the Chinese financial market received little strain during the crisis. While during the 2008 world financial crisis, global financial markets suffered severe disasters and the majority of stock indexes lost over 30% of their values in 2008. Plenty of financial institutions have been taken over by the government. The Chinese economy did not escape from the contagion either. For the previous two financial crises, there are some features in common. The 1997 Asian financial crisis burst in currency markets then swiftly spread to stock markets. While the 2008 world financial crisis broke out with the bursting of the US housing bubble, which quickly caused values of securities to plummet and damaged global financial institutions. Therefore, the relationships between currency markets and stock markets are widely concerned by academics and practitioners, since it is believed that spillover effects exist between the two markets (Abdalla and Murinde, 1997; Phylaktis and Ravazzolo, 2005; Lin, 2012).

The classical economic theory implies that there is a relationship between currency movements and stock market performance, which can occur in two directions. The first group focuses on the current account balance (or the trade balance) that was proposed by Dornbusch and Fischer (1980), which is notable for the "flow-oriented" exchange rate models. Supporters of these models declare that exchange rate fluctuations have a significant impact on the international competitiveness and thereby affecting growth and real income. Furthermore, stock prices react to exchange rate fluctuations since the current value of future cash flows of firms is expressed and interpreted by stock prices. The second group supports the "stock-oriented" exchange rate models (Branson, 1981; Frankel, 1983), which suppose that the shock from stock markets influences aggregate demand through the channel of wealth and liquidity effects, and therefore have an impact on the money demand (Gavin, 1989).

Spillover effects in financial markets have been a research focus in the field of macroeconomic and finance for decades. Empirical findings in the existing literature vary among different studies due to the application of different research methods and datasets. Generally, the dynamic relationship between the stock market and the foreign exchange market is found to be bidirectional (Bahmani-Oskooee and Sohrabian, 1992; Granger et al., 2000; Pan et al., 2007; Rjoub, 2012), or unidirectional (Kim, 2003; Abdalla and Murinde, 1997; Lin, 2012). The spillovers could either run from stock prices to exchange rates or from exchange rates to stock prices. Added to that, spillover effects are much more evident during the financial crisis (Granger et al., 2000; Fang, 2002). However, some studies find that there is no long run relationship between the currency market and the stock market (Tabak, 2006; Ibrahim, 2000; Nieh and Yau, 2010).

The Chinese financial market has received significant attention from policymakers and investors in recent years, which might partly be due to the fast growth of the Chinese economy sine the 1980s. The real sense of the Chinese stock market built in the early 1990s since the setting up of Shanghai and Shenzhen Stock Exchanges. The young Chinese stock market experienced fluctuations within a small range during the 1997 Asian financial crisis due to the implementation of a non-devaluing RMB policy and an effective fiscal policy. Although the 2008 world financial crisis placed strain on the Chinese capital market, but the effect was small and limited, according to the speech of Gang Yao, Vice president of the China Securities Regulatory Commission (CSRC), on the Boao Forum for Asia Annual Conference 2009. He pointed out that a series of risk management measures that implemented by the

CSRC effectively helped to maintain the stability of the Chinese capital market.[42] The managed floating exchange rate regime and the increasingly accumulated foreign reserves play an important part in withstanding external shocks. As a matter of fact, the Chinese stock market was affected by financial shocks although not to the same extent as other Asian stock markets. The mainland Chinese stock market lived through hard times during the Asian financial crisis. The Shanghai A-Share Index and the Shanghai B-Share Index had an annual drop of 65.38% and 69.69% of their values, respectively.[43] Moreover, historical statistics of the RMB foreign exchange rate (USD to RMB) show that the Chinese currency has been appreciating since 1994. Practitioners and investors find that changes in the exchange rate usually have a significant impact on stock prices. Therefore, an increasing number of studies on the Chinese financial market appear since the 1990s, which are interested in exploring spillover effects in the Chinese financial market.

It is apparent that there are a number of studies investigating spillover effects between the foreign exchange market and stock market in China. An earlier study on the Chinese financial market from (Bailey, 1994) suggests that foreign capital shares in the Chinese stock market are not entirely segmented from global financial conditions. Although there is no long run equilibrium relationship between the RMB real effective exchange rate and stock prices, Zhao (2010) suggests that the bidirectional relationship exist between stock prices and exchange rate changes in the short run. However, Nieh and Yau (2010) claim that there is no bidirectional relationship between exchange rates and stock prices. They find that only an asymmetric (unidirectional) relationship exists running from the foreign exchange rate to the Shanghai A-share index. Generally, these studies have examined the nexus between the returns of market portfolios and exchange rate changes. Nevertheless, some basic foundations about the Chinese stock market are ignored in these studies. The Chinese stock market is constituted by RMB ordinary shares (known as A-share) and foreign capital shares (known as B-share). A-shares consist of the Shanghai A-share and the Shenzhen A-share, which are listed in the Shanghai Stock Exchange (SSE) and the Shenzhen Stock Exchange (SZSE), respectively. Similarly, B-shares also have two categories: the Shanghai B-share and the Shenzhen B-share, which are traded in the US dollar (USD) and the Hong Kong Dollar (HKD), respec-

[42]Yao, G.(2009). World Crisis had Limited Effects on the Chinese Stock Market. Available: Http://finance.people.com.cn/GB/9152530.html. Last accessed 20th April 2014.

[43]See the 2008 research reports of the Shanghai Stock Exchange.

tively. Therefore, the corresponding foreign exchange rates are the USD to RMB (USD/RMB) and the HKD to RMB (HKD/RMB). In addition, the shock from the Hong Kong stock market, specially the Hang Seng Index (HSI), is closely monitored by many investors. Therefore, any studies on spillover effects in the Chinese financial market only using the returns of the Shanghai stock index, the Shanghai A-Share and the foreign exchange rate of USD/RMB could not fully capture real spillovers. Concerning the market segmentation of the Chinese stock market, both A-shares and B-shares from the SSE and the SZSE, and the HSI, as well as the corresponding exchange rates of USD/RMB and HKD/RMB should be taken into account in order to make a full exploration of spillover effects in the Chinese financial market. Moreover, the RMB exchange rate is partially managed by Chinese authorities, the currencys trading band was widened from a daily range of 0.3% (1994) to 1% (2012). Hence the investigation of spillovers in the Chinese financial market using different sample periods might generate different results.

In exploring the dynamic relationship between exchange rate changes and stock prices, the conventional Granger causality test (Mok, 1993; Abdalla and Murinde, 1997; Pan et al., 2007) and cointegration approach (Nieh and Lee, 2002; Kim, 2003; Lin, 2012) are commonly used in the existing literature. Following Ibrahim (2000) and Phylaktis and Ravazzolo (2005), this chapter applies the multivariate vector autoregressive (VAR) model to examine the causality between exchange rate changes and stock returns in China. Considering contemptuous effects between the two markets, the conventional Structural VAR (SVAR) is carried out in this chapter. The SVAR model could be identified by imposing restrictions on the short run or long run parameters (Sims, 1980; Blanchard and Quah, 1989; Canova and Nicoló, 2002). Zero and sign restrictions are usually imposed building upon theoretical assumptions. However, which parameters should be imposed as zero signs? Sometimes this is really counterintuitive. In addition, the statistical validity of these restrictions cannot be tested and the identification technique is often inadequate to interpret some of the shocks of interest. Fortunately, the Markov Switching SVAR (MS-SVAR) approach estimates the volatility of shocks in a hidden Markov process and allows the error term of the SVAR model to be state-dependent, which captures the shocks across states (Sims et al., 2008; Lanne and Lütkepohl, 2010; Herwartz and Luetkepohl, 2011). One of the key advantages is that the SVAR with Markov switching in regimes can be easily identified by simply imposing restrictions on the number of regimes and the variance-covariance matrices, while additional restrictions on the short run and long run matrices are unnecessary.

Unlike previous studies on the Chinese financial market, this chapter investigates the causal relationship between exchange rate changes and stock returns using the multivariate VAR approach. Both RMB ordinary shares and foreign capital shares listed in the SSE and the SZSE, as well as the exchange rates of USD/RMB and HKD/RMB, are main endogenous variables included in the empirical model. More importantly, the HSI is incorporated in the framework to test interactions between the Hong Kong stock market and the mainland Chinese stock market. To get a preliminary overview of structural innovations, the conventional SVAR model is carried out by imposing restrictions on short run parameters. Due to certain drawbacks and inefficiencies of the SVAR model, this chapter models the volatility endogenously in the Markov regime switching mechanism building upon the SVAR model, which captures spillovers in the Chinese financial market and reflects the tough and tranquil periods of the Chinese economy. The sample for this chapter is constituted by a set of daily stock indexes and foreign exchange rates. Furthermore, two subsamples for the 1997 Asian financial crisis and 2008 global crisis are investigated in this chapter to observe different market behaviours in crisis periods.

The remaining sections of this chapter are organised as follows. The empirical studies on interactions between exchange rate changes and stock returns are given in section 3.2. Section 3.3 describes econometric models and related technical inferences. Section 3.4 gives the data description and preliminary statistics. Empirical results are presented in Section 3.5 and the last section concludes. More detailed representations about the multivariate VAR and conventional SVAR, the Markov switching SVAR model are given in Appendix A and B, respectively.

3.2 Exchange Rate Changes and Stock Returns: the Empirical Literature

The relationship between exchange rate changes and stock returns is not a new topic, but it still receives significant attention from academics, practitioners and policymakers, since there is an increasing need for managing financial risks and getting a deep insight into interactions between currency markets and stock markets. The extant studies mainly explore the existence of the dynamic relationship between exchange rate changes and stock prices (or stock returns) (Muhammad et al., 2002; Kim, 2003) and investigate the impact of financial crisis on economic development (Fang, 2002; Granger et al., 2000). More specifically, these studies aim to find whether the comovement between exchange rates and stock prices is bidirectional (Rjoub, 2012) or unidirectional (Abdalla and Murinde, 1997) building upon the classical economic theory on the dynamic relationship between exchange rates and stock prices. Those bidirectional relationship supporters indicate that exchange rate models have two directions, which can be the direction of "flow-oriented" and "stock-oriented" simultaneously. Those unidirectional relationship backers suggest that the causality could run either from exchange rates to stock prices or from stock prices to exchange rates. The motivation and research framework of these studies do not exhibit any significant differences. In order to get an insight into these studies, this chapter reviews the existing literature according to the division of different economies:[44] emerging economies, developed economies, and the interplay between emerging economies and developed economies.

3.2.1 Linkages between Exchange Rate Changes and Stock Returns in Emerging Economies

The rise of emerging markets and ongoing openness of the world economy strengthens the mutual interdependence and interaction of the global economy. However, these increasing interactions might bring uncertainties to emerging markets since unexpected external shocks usually have a significant impact on financial markets of emerging economies. The returns of financial assets suffer from dramatic changes in the currency market, and in return, fluctuations of asset returns might have spillover effects on currency markets. In the existing literature, the nexus between exchange rate changes and stock returns in emerging markets have been studied from a broad perspective. Applying the Markov regime-switching approach, Chkili and Nguyen (2013) suggest that stock markets have a significant impact on exchange rates in BRICS countries (Brazil, Russia, India, China and South Africa); the correlation between exchange rates and stock returns in South African is positive (Tovar-Silos and Shamim, 2013); for the regime-dependent relationship, fluctuations in stock prices

[44]This chapter combines the classification of emerging economies pursuant to those categories from the International Monetary Fund (IMF)(July 2012) and the Emerging Market Global Players (EMGP) project at Columbia University (April 2013), as well as the list tracked by *The Economist*.

yield asymmetric responses to shocks from the currency market, which means that exchange rate changes affect transition probabilities across regimes (Walid et al., 2011). Moreover, bidirectional relations have been found between exchange rates and stock prices in the case of Turkey (Rjoub, 2012) and China (Zhao, 2010). For the bidirectional correlation, there are significant transmission shocks and volatilities exist amongst these indicators (Turkyilmaz and Balibey, 2013). Nevertheless, no long run equilibrium exists between stock prices and exchange rates in Brazil (Tabak, 2006) and in BRIC countries (Gay Jr et al., 2011). If the empirical model is built upon different regression frameworks, linear and nonlinear Granger causality tests might generate different results (Tabak, 2006). Linear Granger causality tests conclude that a negative correlation exists between stock prices and exchange rates (stock prices cause exchange rate changes), while the nonlinear test suggests that exchange rates causes changes in stock prices. Under certain circumstances, stock returns suffer from the internal political risk combined the change in the exchange rate (Bailey and Chung, 1995).

In the existing literature, Asian emerging economies are of interest to many researchers due to their increasing influences in the Asia-Pacific region and their connections to the world economy. Abdalla and Murinde (1997) explore the interplay of exchange rates and stock returns in emerging economies, such as India, Pakistan, Korea and Philippines, applying a bivariate VAR model. Unidirectional causality from exchange rates to stock returns has been found in these economies except Philippines. In 1997, the Asian financial crisis broke out due to the collapse of the currency market in Thailand, and then spread to almost all south and east Asia countries. Since then, an increasing number of studies are interested in examining spillovers in Asian financial markets during the crisis period. Serious shocks of currency depreciation on stock returns have been found in Asian Tigers (Fang, 2002).[45] Granger et al. (2000) conclude that exchange rates lead stock prices in South Korea and stock prices are negatively correlated with exchange rates in Philippines, while a bidirectional relationship exists in Hong Kong, Singapore, Thailand, Malaysia and Taiwan, and no recognizable impact is revealed in Indonesia. In a comparative study, before the Asian financial crisis, Pan et al. (2007) found that there is a significant effect from exchange rates to stock prices in Malaysia and Thailand, and a bidirectional relationship exists between the equity market and the foreign

[45] The four Asian Tigers refer to Hong Kong, Singapore, Taiwan and South Korea.

exchange market in Hong Kong, Korea and Singapore, but no significant causality could be found from stock prices to exchange rates during the Asian financial crisis. The strong comovement between exchange rates and stock returns during the crisis is found in Asian emerging economies (Lin, 2012), which represents that transmission channels are from stock prices to exchange rates. Moreover, evidence from the Association of Southeast Asian Nations (ASEAN)-5 economies indicates that the negative impact of exchange rates on stock prices transmits through the channel of capital mobility (Liang et al., 2013). There are more studies on the relationship between exchange rates and stock prices in Asian emerging economies, for instance, no long run relationship could be found in Malaysia (Ibrahim, 2000) and China (Nieh and Yau, 2010), and weak bidirectional causality exist in Hong Kong (Mok, 1993) and Pakistan (Jawaid and Haq, 2012).

3.2.2 Interactions between Exchange Rate Changes and Stock Returns in Developed Economies

The foreign exchange market is becoming increasingly integrated with the equity market in the process of economic globalisation. During the process, stock markets in developed countries have sophisticated regimes and might withstand currency shocks. However, existing studies have found evidence of exchange rate risks on stock prices. The interplay between stock prices and exchange rate changes is known as volatility spillovers (Kanas, 2000).[46] Dominguez (2001) points out that exchange rate changes have significant effects on both firm level and sectoral level stock prices in industrial countries (UK, France, Germany, Italy, Japan and Netherlands). The interaction between the real exchange rate and stock prices (S&P 500) in the US is bidirectional in the short run (Bahmani-Oskooee and Sohrabian, 1992), but the correlation is negative in US financial markets which runs from the real exchange rate to stock prices (Kim, 2003; Choi et al., 1992). Unlike existing studies, Nieh and Lee (2002) find that there are no long run relationships between exchange rates and stock prices in G-7 countries, only a short run correlation (for one day)

[46] Kanas (2000) mentions that the majority of existing studies on the dynamic relationship between exchange rate changes and stock prices are concentrated on the first moment of related distributions, ignoring the second moment. While our study measures spillovers between exchange rate changes and stock returns using the MS-SVAR model, which could model both the first and second moments of spillovers (mean and volatility spillovers).

exists in German, Canadian and British financial markets.[47] They also suggest that stock prices and exchange rates are not reliable for predicting the future value both in the long run and the short run. Moreover, applying the Granger causality test to the US stock market, Vygodina (2006) claims that firm size might change the relationship between exchange rates and stock prices over time since large-cap shares might have effects on exchange rates but small-cap stocks do not exhibit any spillover effects to exchange rates. Additionally, Ma and Kao (1990) suggest that currency appreciation has a negative impact on the domestic stock market in an export-dominated economy since it weakens the competitiveness of exports markets, while an appreciated currency lowers the cost of imports and produces a positive effect on the domestic stock market if it is an import-dominated economy. Besides spillovers between the two markets, changes in the fiscal policy might also have an impact on the interaction between exchange rates and stock prices. Earlier research of Gavin (1989) argues that the announcement of good news in the fiscal policy will generate a negative relationship between stock prices and real exchange rate when aggregate demand shocks are unanticipated, but the correlation is positive if the implementation of the announced policy is delayed too long. For practical implications, Homma et al. (2005) suggest that investors need to pay attention to the foreign asset position (international assets minus liabilities) of these listed firms and make appropriate responses to exchange rate fluctuations.

3.2.3 Cross-Market Interactions of Exchange Rate Changes and Stock Returns

Open economies benefit from rapidly growing foreign trade and inflow of foreign capital, but at the same time these economies might suffer unexpected shocks from external environments. The historical cross-country crisis gave the world a disciplinary warning that each country needs to respond to cross-market shocks and make swift adjustments accordingly, such as the 1997 Asian financial crisis and the 2008 world financial crisis. Currency markets of emerging economies are subject to spillovers from advanced financial markets. The crisis happened in one emerging country might also spread to neighboring emerging economies. Coudert et al. (2011) investigate the effect of contagion from advanced financial markets to emerging mar-

[47] The one day correlation means the currency depreciation drags down or stimulates stock returns on the following day.

kets applying a nonlinear smooth transition regression model based on the sample of 21 emerging economies. They conclude that this impact is intensified during the global financial crisis. It is the pegged US dollar currency policies in emerging countries that result in the expansion of the financial turmoil at the outset, and exchange rate changes further exaggerate the turmoil in stock markets. There are a number of studies on cross-market interactions. Phylaktis and Ravazzolo (2005) claim that the positive correlation between exchange rates and stock prices in Pacific Basin economies is linked through the channel of the US stock market, but the shocks on other markets during the financial crisis are temporal. Kubo (2012) suggests that Asian stock markets and the US stock market are integrated, which has been intensified, particularly in information technology sectors. These findings imply that the exchange rate changes have a negative impact on domestic stock prices, which means that financial markets of these economies are vulnerable to variations in the international portfolio. Further, Chiang et al. (2000) find that the US and Japanese stock markets have a positive impact on other Asian stock markets. Different from the existing evidence that foreign exchange markets affect stock markets, their bivariate autoregressive conditional heteroskedasticity (GARCH) model represents that stock returns are positively correlated with domestic currency (not foreign currencies). In addition, Yau and Nieh (2009) investigate effects of exchange rates on stock prices in Taiwan, Japan and the US, and confirm the existence of the long run relationship (but no short run causality). Although currency shocks are found to affect stock prices both in the US and Japan, Mun (2012) shows that the US stock market is not affected by macro shocks from Japan but asymmetrically responds to domestic growth and the interest rate. With regard to practical implications, the cross-country industry analysis investigated by Griffin and Stulz (2001) suggests that currency shocks are not economically important for investors since they can affect firm returns in a number of ways. This indicates that currency shocks have little effect on firm values. The exogeneity of the foreign exchange rate has also been recognized by Grammig et al. (2005) based on the evidence of cross-listed German companies in the NYSE market and the XETRA market. Their study also provides more evidence for understanding the volatility of the NYSE market.

In general, previous studies on the comovement between exchange rate changes and stock returns can be summarised into three categories. The most common evidence is the bidirectional relationship, which means that changes in exchange rates cause stock price fluctuations, and stock price fluctuations also affect exchange rates (Mok, 1993; Granger et al., 2000; Bahmani-Oskooee and Sohrabian, 1992; Pan et al., 2007; Zhao, 2010; Rjoub, 2012). The second category is the unidirectional relationship between exchange rates and stock returns, which might either run from exchange rates to stock prices or from stock prices to exchange rates (Choi et al., 1992; Abdalla and Murinde, 1997; Kim, 2003; Lin, 2012). Considering the cross-border interactions in the global market, spillover effects are more likely to disseminate from advanced financial markets to emerging markets (Phylaktis and Ravazzolo, 2005; Coudert et al., 2011; Kubo, 2012), and the crisis happening in one country might also spread to its neighbouring economies. The third type of evidence is that there is no long run relationship between exchange rate changes and stock returns (Tabak, 2006; Ibrahim, 2000; Nieh and Yau, 2010). Moreover, the practical implication for investors and shareholders is that foreign exchange rate shocks are exogenous for cross-listed firms, which have little effect on firm returns (Griffin and Stulz, 2001; Grammig et al., 2005).

This chapter aims to re-examine spillover effects between exchange rate changes and stock returns in China applying several advanced econometric methods based on a high frequency dataset. This chapter differs from the existing literature mainly in three ways: (1) regarding research methods, the multivariate VAR approach rather than the bivariate VAR is applied to test the causal relationship, then the conventional SVAR is estimated to observe structural innovations between exchange rate changes and stock returns. Considering potential drawbacks of the SVAR model, the Markov switching SVAR approach is introduced to capture the volatile structure of the Chinese financial market; (2) for data selection, both RMB ordinary shares and foreign capital shares, the HSI and foreign exchange rates of USD/RMB and HKD/RMB are considered in the empirical analysis; and (3) the effects of the 1997 Asian financial crisis and 2008 world financial crisis on the dynamic correlation between exchange rate changes and stock returns are separately examined in this chapter.

3.3 Econometric Models

3.3.1 Theoretical Model and Conventional Structural VAR Model

Stock indexes and exchange rate changes are endogenous variables included in the theoretical model. The basic assumption on the theoretical framework is that those stocks listed in the Shanghai stock market receive shocks from the Shenzhen stock market and the Hong Kong stock market, as well as changes in exchange rates (USD/RMB and HKD/RMB). The causality between stock returns and exchange rate changes is examined using the vector autoregressive model. Initially, the reduced model is an unrestricted VAR which includes a set of endogenous variables Y_t^i. $Y_t^i = \{SR_t^{SHAI}, SR_t^{SHBI}, SR_t^{SZAI}, SR_t^{SZBI}, ER_t^{HSI}, ER_t^{USD/RMB}, SR_t^{HKD/RMB}\}$. The five stock indexes in Y_t^i are the returns of the SHAI, SHBI, SZAI, SZBI and HSI. The remaining two series are exchange rate changes in USD/RMB and HKD/RMB.

Previous studies indicate that the dynamic relationship between exchange rate changes and stock returns could be investigated at both the micro and macro levels (Abdalla and Murinde, 1997). This chapter explores the correlation at the macro level. The existing literature on these linkages are found to be bidirectional ($SR_t^j \Leftrightarrow ER_t^i$), such as the studies of Mok (1993), Pan et al. (2007), Rjoub (2012), or unidirectional ($SR_t^j \Leftarrow ER_t^i$ or $SR_t^j \Rightarrow ER_t^i$), such as the paper of Choi et al. (1992), Kim (2003) and Lin (2012), or no long run equilibrium (Tabak, 2006; Nieh and Yau, 2010), that is $SR_t^j \neq ER_t^i$. The commonly used conventional econometric method in examining the correlation between exchange rates and stock returns is the bivariate Granger causality test (Mok, 1993; Abdalla and Murinde, 1997; Pan et al., 2007), which is built upon the bivariate VAR (BVAR) model:

$$ER_t = \sum_{j=1}^{m} \alpha_j ER_{t-j} + \sum_{j=1}^{n} \beta_j SR_{t-j} + \varepsilon_t \tag{3.1}$$

$$SR_t = \sum_{j=1}^{m} \gamma_j ER_{t-j} + \sum_{j=1}^{n} \eta_j SR_{t-j} + \mu_t \tag{3.2}$$

When β_j=0, stock returns fail to Grange-cause exchange rates. exchange rates cannot Grange-cause stock returns only if γ_j=0. If more than two endogenous variables are included in the framework, the general autoregressive distributed lag (ARDL) model is introduced in testing the causality (Lin, 2012). Apart from stock returns and exchange rate changes, other variables which are supposed to affect the two main indexes can be incorporated into the error correction model of the ARDL, then the test for causality is the implementation of Wald test. Moreover, the extended multivariate model has been introduced by Dolado and Lütkepohl (1996), Ibrahim (2000) and Phylaktis and Ravazzolo (2005). The test of transmission channels of stock returns (or exchange rates) is carried out with a Wald test of VAR estimates. Other methods commonly used in investigating the dynamic relationship between exchange rate changes and stock returns are the EGARCH model with a regime-switching (Walid et al., 2011), the cointegration approach (Kim, 2003; Nieh and Lee, 2002), cointegration followed by a GARCH (EGARCH for bivariate or MGARCH for multivariate) model (Kanas, 2000; Zhao, 2010). For these empirical studies, the existence of causality between stock returns and exchange rates depends on the significance of estimated coefficients.

The Chinese stock market has its unique characteristic in the classification of foreign capital shares and RMB ordinary shares, as well as cross-listed shares.[48] When a stock suffers shocks from the foreign exchange market, the stock listed in another market from the same company might also receive spillovers from both the former stock market and the foreign exchange market. On the contrary, foreign exchange rates are subject to the shocks from the RMB ordinary stock market and the foreign capital stock market. Considering the reduced form of the k-dimensional VAR model with p-th lags (Lütkepohl, 2005):

$$y_t = Dd_t + A_1 y_{t-1} + \cdots + A_p y_{t-p} + u_t \tag{3.3}$$

Where $y_t = (y_{1t}, \cdots, y_{nt})'$ is a $n \times 1$ dimensional vector. D is the coefficient matrix of deterministic components d_t. More details about the multivariate VAR model can be found in Appendix A. The conventional causality test based on the VAR model relies on the Wald test of lagged terms in matrices A_i. However, the standard VAR approach is subject to unrestricted properties of shocks. If all variables in the VAR system are integrated I(1), then a vector error correction model (VECM) of equation (3.3) combines the representation of both long run and short run effects. Therefore, it is easy for researchers to impose certain restrictions on these shocks (Lanne and Lütkepohl, 2010). The VECM of equation (3.3) is written in the following form:

[48] Cross-listed share means that firms have their shares listed in two different markets, such as the Shanghai and Hong Kong stock markets.

$$\Delta y_t = D^* d_t^* + \alpha\beta' y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + u_t \tag{3.4}$$

Where β denotes the long run relationship and α is the loading matrix. Δ is a difference operator. D^* is the parameter matrix of the unrestricted deterministic term d_t^*. Γ_i captures short run dynamics. In reality, most empirical studies are carried out based on theoretical assumptions, which are needed to impose some restrictions to further identify the model. Nevertheless, the reduced VAR falls short of imposing these restrictions and the model only focuses on lagged terms (past shocks) without taking into consideration simultaneous shocks. Further strong assumptions which are more directly associated with theories could be imposed in the structural VAR (SVAR) model. To specify the SVAR, re-write equation (3.3) as $\Phi(L)y_t = u_t$. where $\Phi(L) = I - \Phi_1 L + \Phi_2 L^2 \cdots + \Phi_p L^p$, and in which $\Phi_0 = I$. The SVAR model incorporates additional contemporaneous endogenous shocks into the framework (Lütkepohl, 2005; Lanne et al., 2010), and the typical AB model form of the SVAR is expressed as:[49]

$$Ay_t = D^s d_t + A_1^s y_{t-1} + ... + A_p^s y_{t-p} + B\varepsilon_t \tag{3.5}$$

Equation (3.5) is the standard SVAR model with k-dimensional vector of endogenous variables in y_t. A, D^s, $A_i^s (i = 1 \sim p)$ and B are $k \times k$ structural form of matrix arguments. See Appendix A for more details about the estimation and identification of the SVAR model.

The SVAR model could be identified by imposing certain types of restrictions on short run parameters or long run autoregressive parameters, which could be zero or sign restrictions based on theoretical assumptions. However, the statistical validity of these restrictions cannot be tested and the kind of identification technique is usually inadequate to interpret some of the shocks of interest. Moreover, we need to notice that the error term u_t is often assumed to be normally distributed in the SVAR model. Essentially, no theoretical framework supports this hypothesis and it is also unnecessary for the asymptotic inference. Added to that, the residuals of the SVAR model are not normal in empirical studies. Fortunately, the existence of

[49] In the SVAR model, A is the parameter matrix capturing contemporaneous shocks. B is the covariance matrix. To identify the SVAR, we need to identify both A and B. Hence it is called AB model.

various error covariance matrices across regimes in structural shocks can be easily identified using the Markov switching (MS) mechanism in those regimes (Sims et al., 2008; Lanne et al., 2010; Herwartz and Luetkepohl, 2011).

3.3.2 SVAR Model with Different Volatility Regimes

Financial time series usually have properties of behaviour changes nearly in any range of observations. These changes could be caused by policy changes (Hamilton, 1989, 1994) or external crisis (Jeanne and Masson, 2000). Changes in the behaviour of time series data can be represented in a Markov process (MS). The earliest MS model for the investigation of dynamic structures of economic time series were introduced by Hamilton (1989), who suggested that the univariate y_t could be estimated by a k-th order of MS autoregressive (MS-AR) with regime changes across the mean and variance. Multiple time series models with regime-switching are further developed by Krolzig (1997). The MS-VAR allows for heteroskedasticity in a nonlinear pattern, which has been widely used in modelling business cycle, monetary policy, dynamic risk and financial market volatilities (Krolzig, 2001; Anas et al., 2004; Kim et al., 2008; Guo et al., 2013).

In the MS-SVAR framework, 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 $t = (0, \pm1, \pm2, ... \pm M)$ and transition probabilities are: $p_{ij} = Pr(s_t = j|s_{t-1} = i), i, j = 1, ..., M$.

$$u_t|s_t \sim N(0, \Sigma_{s_t}) \tag{3.6}$$

Generally, the distribution of u_t conditional on s_t is assumed to be normal, but this is just for the convenience of setting up the likelihood function. Pseudo maximum likelihood(ML) estimators are commonly used if the conditional normality of $u_{t|s_t}$ does not hold. Hence, the normality assumption is not necessary for identifying shocks. See more details about the MS-SVAR model in Appendix B.

Rewrite the SVAR equation (3.5) as: $A_0 y_{t-i} = F x_{t-i} + \varepsilon_t$, where F_i is the coefficient matrix and x_{t-i} is a vector of lagged variables. Sims et al. (2008) propose the Markov switching SVAR (MS-SVAR) using a Bayesian form, but all matrices can be state-dependent:

$$A(s_t)y_{t-i} = F(s_t)x_{t-i} + \Xi^{-1}(s_t)\varepsilon_t \tag{3.7}$$

Where Ξ is a diagonal matrix and s_t is defined as m states Markov process with transition matrix $Q = q_{i,j}$ (transition probabilities). Equation (3.7) allows all matrices to switch in a markov process. The other two types of MS models are coefficients-switching and variances-switching models, respectively.

$$\Xi(s_t)A(s_t)y_{t-i} = \Xi(s_t)F(s_t)x_{t-i} + \varepsilon_t \tag{3.8}$$

$$Ay_{t-i} = Fx_{t-i} + \Xi^{-1}(s_t)\varepsilon_t \tag{3.9}$$

The maximum likelihood (ML) function is commonly applied in estimating the MS-SVAR model, which is carried out when the conditional normality distribution does not hold. Alternatively, the expectation maximization (EM) algorithm can be an alternative for estimating the MS-SVAR model (Hamilton, 1994; Krolzig, 1997; Herwartz and Luetkepohl, 2011).

To estimate the MS-SVAR, the selection of the number of states really matters and influences the model output. Considering changes in the state of stock returns, two or three states are normally selected,[50] but we have to test the validity from the statistical information perspective. Normally, log likelihood statistics together with the Akaike information criterion (AIC) and the Bayesian information criterion (BIC) are reliable approaches to determine the best MS model (Psaradakis and Spagnolo, 2006; Herwartz and Luetkepohl, 2011).

3.4 Data Description and Preliminary Analysis

3.4.1 The Data

Due to the unavailability of daily exchange rates before 1994, the sample of this chapter ranges from 1 January 1994 to 31 December 2012. Daily exchange rates of USD/RMB and HKD/RMB were collected from the State Administration of Foreign Exchange.[51] Five stock indexes are collected to explore the dynamic correlation between these stock markets, namely the Shanghai A-share Index (SHAI), the

[50]The shocks to stock returns and exchange rate changes can be positive, negative or no changes, and then the volatility state could be selected accordingly.

[51]The State Administration of Foreign Exchange is a financial branch of the Chinese State Council, which is administered by the People's Bank of China.

Shanghai B-share Index (SHBI), the Shenzhen A-share Index (SZAI), the Shenzhen B-share Index (SZBI) and the Hang Seng Index (HSI). They can be obtained from the website of the NetEase company. The SHAI and the SZAI are RMB ordinary shares, which are listed in the Shanghai and Shenzhen Stock Exchanges, respectively. The SHBI and the SZBI are foreign stock shares, which are traded in USD and HKD, respectively. Foreign investors with legal identifications and accounts can invest in foreign stock markets (Shanghai B-shares and Shenzhen B-shares). However, Chinese authorities are currently trying to incorporate the Shenzhen Stock Exchange into the Shanghai Stock Exchange. Any applications of issuing new foreign shares need to be submitted to the Shanghai Stock Exchange. This means that the Shenzhen Stock Exchange will not issue new foreign stocks any more. Moreover, the HSI represents the market trend of the Hong Kong stock market, which could give investors some implications while they are investing in those cross-listed shares.[52] In the Chinese stock market, more than eighty mainland Chinese stocks cross-list in the Shanghai (or Shenzhen) stock market and the Hong stock market. Therefore, incorporating both mainland stock market indexes and the HSI into the theoretical framework is essential for investigating spillovers between exchange rate changes and stock returns in the Chinese financial market.

It is argued by many researchers that the interest rate should be included in the empirical model, since it affects stock returns to a greater extent. While the conventional "flow-oriented" and "stock-oriented" exchange rate models only consider interactions between exchange rates and stock prices. For other shocks, such as the interest rate and GDP growth rate, are excluded in this chapter. Moreover, the size of the Markov switching model grows exponentially with the increase in the number of explanatory variables and regimes. Therefore, it is better to estimate the simple model and only focus on spillover effects between exchange rates and stock returns.

Figure 3.1 represents plots of exchange rates. The RMB foreign exchange rate experienced a long stable period (1995 to mid-2005) due to the fixed exchange rate regime. Since July 2005, the Chinese currency has been appreciating, except during the crisis period between 2008 and mid-2010. During the 1997 Asian financial crisis, the RMB exchange rate did not show any significant changes due to the implementation of a fixed currency policy. The graph also demonstrates that the RMB exchange rate became relatively stable during the 2008 world financial crisis, which

[52] See the profile of Hang Seng Indexes Company Limited.

was possibly caused by the government intervention in the foreign exchange market.

Figure 3.1 also gives plots of stock indexes. It is apparent that all indexes had a dramatic increase from early 2006 to late 2007 (the bull market), but suffered severe shocks during the world financial crisis, and then rebounded again after the crisis.[53] Comparatively, the 1997 Asian financial crisis had less impact on the Chinese stock market. Evidently, the SHAI did not exhibit any significant recessions during the 1997 Asian financial crisis. Possible reasons for this are that the Chinese government implemented the non-devaluing policy at that time and RMB ordinary shares are less likely to receive shocks from exchange rate fluctuations. The lower part of Figure 3.1 gives the historical data of the HSI from early 1994 to the end of 2012. Intuitively, the figure looks similar to the other two foreign capital shares since the shares that are traded in foreign currencies are more sensitive to changes in the exchange rate.

3.4.2 Data Transformation and Descriptive Statistics

The aim of this chapter is to investigate spillovers between exchange rate changes and stock returns, hence the measurement of exchange rate changes and stock returns are important at the data transformation stage. Exchange rate changes are a good measure of evaluating exchange rate regimes.[54] Coudert et al. (2011) measure exchange rate changes applying squared monthly exchange rate returns, while others prefer to express exchange rate changes as natural logarithms of the division between two continuous closing values (Kanas, 2000; Homma et al., 2005; Zhao, 2010; Walid et al., 2011). Following these studies, stock returns are denoted as the difference between natural logarithms of two consecutive closing prices. Exchange rate changes ER_t^i and stock returns SR_t^j are calculated according to the following equations:

$$ER_t^i = ln\left(\frac{p_t^i}{p_{t-1}^i}\right) \qquad SR_t^j = ln\left(\frac{p_t^j}{p_{t-1}^j}\right) \tag{3.10}$$

[53]Most Chinese investors became rich overnight during 2006 and 2007, whereas plenty of investors lost their wealth during the 2008 global financial crisis.

[54] Two methods are commonly used in measuring the change in the exchange rate: (1) calculate the difference between natural logarithms of two consecutive exchange rate values; and (2) get the σ^2 from the GARCH estimates.

Where p_t^i denotes different types of exchange rates (USD/RMB or HKD/RMB) at time t. p_t^j represents stock indexes (j=1 to 5 for the SHAI, SHBI, SZAI, SZBI, HSI, respectively) at time t. Figure 3.2 displays plots of exchange rate changes and stock returns. The striking feature of exchange rate changes is that both graphs (USD/RMB and HKD/RMB) have a long spike around the 2005 RMB policy reform and intense fluctuations during the 2008 world financial crisis. Nevertheless, stock returns exhibit highly volatile properties which imply the instability of the Chinese stock market.

Table 3.1 reports descriptive statistics of exchange rate changes and stock returns. In panel A, the two exchange rate series do not show too much difference in their means and standard deviations, and both are negatively skewed with a high excess kurtosis. The fluctuation of USD/RMB has a longer and fatter left tail and higher kurtosis compared with HKD/RMB. The negative skewness and high kurtosis together with the normality test further confirm non-normal properties of these series. In panel B, the return of the SZAI has the highest mean, and SZBI returns have the highest standard deviation. SHAI returns have the highest skewness and kurtosis within the group of stock returns. Finally, normality tests reject the null and suggest that these series are not normally distributed. Added to that, Q-statistics reject the null hypothesis and imply the properties of autoregressive conditional heteroskedasticity of these series.

3.4.3 Stationary Test

The VAR model requires that all endogenous variables should be stationary, this section therefore presents a general analysis of unit root tests. The stationarity test of exchange rate changes and stock returns is carried out applying the Augmented Dick Fuller (ADF) test (Dickey and Fuller, 1979) and the Phillips-Perron (PP) test (Phillips and Perron, 1988). For the high frequency data, the Kwiatkowski-Philips-Schmidt-Shin(KPSS) test is not introduced in the chapter since it is specially powerful for small samples (less than 250)(Kwiatkowski et al., 1992), which might not be efficient for large samples. Table 3.2 reports unit root test results. All of these statistics are significant at the 1% level, which indicates the stationarity of these series.

3.5 Empirical Results

This section gives the empirical analysis of spillover effects in the Chinese financial market. This section begins with the investigation of the causality between exchange rate changes and stock returns applying the multivariate Granger causality test, then carries on exploring structural innovations between currency shocks and fluctuation of stock prices using the conventional SVAR, which is identified with restrictions on short run parameters, and finally models spillover effects among these markets based on the MS-SVAR framework.

3.5.1 Multivariate Granger Causality Test

Table 3.3 reports multivariate Granger causality tests of the three panels. Panel A shows the estimates from the whole sample, while panel B and panel C present the results from two subsamples (the 1997 Asian financial crisis and the 2008 world financial crisis). As demonstrated in the table, it is clear that fluctuations in the SHBI have a significant impact on other stock returns and exchange rate changes in the three panels. This finding is common and easy to interpret. The SHBI (traded in USD) represents the market trend of foreign capital shares in the Chinese stock market. Since the Chinese currency is still in a policy of pegging to the USD after the 2005 exchange rate policy reform (Frankel and Wei, 2007), changes in USD/RMB affects firm returns to a greater extent. Although the SZBI (traded in HKD) consists of foreign capital shares, investors are mainly from Hong Kong, Macau and Tai Wan. With the handing over of the right of listing new foreign capital stocks, the SHBI is gradually losing its power in the foreign capital market. Therefore, shocks from the SZBI are weak compared with the SHBI shock. However, the SZBI still exhibits influences on returns of the SHAI, SZAI, HKD/RMB and the HSI (except the subsample from 2008 onwards). Moreover, the SHAI shock has a significant impact on stock returns of the SHBI and SZBI (after 1997 Asian financial crisis), but no contagion can be found in the foreign exchange market. The HSI also shows a significant impact on the SHAI and SHBI, particularly in the two subsamples. With regard to the impact of exchange rate changes, Wald tests reveal that both the changes in USD/RMB and HKD/RMB do not exhibit significant influences on stock returns across three panels.

In general, the multivariate Granger causality test demonstrates that there are no spillovers from RMB ordinary shares (SHAI and SZAI) to foreign exchange markets, which can be expressed as $SR_A \nRightarrow ER$, where the subscript A denotes RMB ordinary shares. However, the strong and significant impact on both foreign exchange markets and stock markets are identified from volatile returns of foreign capital shares, particularly for the SHBI shock, that is $SR_{SHBI} \Rightarrow ER$ and $SR_{SHBI} \Rightarrow SR$. The shock from the SZBI is not as large as those of the SHBI as can be seen from the evidence shown in Table 3.3, which could be concluded that the SZBI has an important impact on the Shanghai stock market and the HKD/RMB. That is $SR_{SZBI} \Rightarrow SR_{Shanghai}$ and $SR_{SZBI} \Rightarrow ER_{HKD/RMB}$. Furthermore, after the 1997 Asian financial crisis and the return of Hong Kong, the HSI has close correlations with the Shanghai stock market, but it cannot affect exchange rate fluctuations of HKD/RMB. Finally, both foreign exchange markets do not cause any shocks to the Chinese stock market ($ER \nRightarrow SR$), but changes in USD/RMB show a strong influence on HKD/RMB ($ER_{USD/RMB} \Rightarrow ER_{HKD/RMB}$).

The findings from the multivariate VAR test are generally consistent with the Chinese currency policy. Exchange rate changes cannot affect stock returns in the Chinese financial market due to the implementation of a managed floating exchange rate policy, but foreign capital share returns have significant effects on exchange rates, which is in accordance with the classical "stock-oriented" economic theory. Since the Hong Kong government implements a linked exchange rate system, the HKD is mainly pegged to the USD. This could be used to interpret why changes in USD/RMB can Granger-cause the fluctuation of HKD/RMB.

3.5.2 A Parsimonious Conventional SVAR Analysis

The SVAR model is widely applied to examine the effect of external shocks on financial markets in open economies (Sims, 1980, 1986; Ben and Alan, 1992; Dungey and Pagan, 2000). While this chapter uses it to analyse structural innovations between exchange rate changes and stock returns in the Chinese financial market. Previous studies have found the existence of spillovers between the foreign exchange market and the stock market (Mok, 1993; Zhao, 2010; Rjoub, 2012). Building upon the multivariate Granger causality test, this section further takes into consideration contemporaneous shocks, which could be examined in the conventional SVAR model. However, the most difficult part of this approach is the imposing of restrictions on the variance-covariance matrix. Under most circumstances, these restrictions have three categories: (1) short run restrictions on the matrix A or A^{-1}, which can be derived from the theoretical background and realities (Sims, 1980; Blanchard and Quah, 1989); (2) sign restrictions on the short run parameters based on theoretical assumptions (Rubio-Ramirez et al., 2005); and (3) long run restrictions on certain combinations of short run parameters and autoregressive parameters (Dungey and Fry, 2009).

In terms of short run restrictions, a triangular Cholesky decomposition which restricts all elements above the diagonal matrix as zeros just identifies the SVAR model. However, which parameters should be imposed as zero? This can be really counterintuitive. This chapter follows the study of Sims (1986) to derive restriction options based on theory assumptions. According to equation (3.5) and its derivatives on structural shocks, short run restrictions of the SVAR model are presented in equation (3.11).

$$\begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} & a_{17} \\ a_{21} & 1 & 0 & a_{24} & a_{25} & a_{26} & 0 \\ 0 & 0 & 1 & 0 & a_{35} & a_{36} & 0 \\ a_{41} & 0 & a_{43} & 1 & 0 & a_{46} & a_{47} \\ 0 & 0 & 0 & a_{54} & 1 & a_{56} & 0 \\ 0 & a_{62} & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & a_{74} & 0 & a_{76} & 1 \end{bmatrix} \begin{bmatrix} u_t^{SHAI} \\ u_t^{SHBI} \\ u_t^{SZAI} \\ u_t^{SZBI} \\ u_t^{HSI} \\ u_t^{USD/RMB} \\ u_t^{HKD/RMB} \end{bmatrix} = \begin{bmatrix} \varepsilon_t^{SHAI} \\ \varepsilon_t^{SHBI} \\ \varepsilon_t^{SZAI} \\ \varepsilon_t^{SZBI} \\ \varepsilon_t^{HSI} \\ \varepsilon_t^{USD/RMB} \\ \varepsilon_t^{HKD/RMB} \end{bmatrix} \tag{3.11}$$

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 chapter assumes that structural innovations from these markets have a contemporaneous impact on the SHAI. The second equation shows that the SHBI receives instantaneous shocks from the SHAI, SZBI, HSI and USD/RMB, but no effects from the SZAI and HKD/RMB. Also changes in HKD/RMB do not affect foreign capital stocks in the Shanghai stock market. The third equation describes that the SZAI responds to the shocks from the HSI and USD/RMB. Equation four gives the description of instantaneous shocks on the SZBI, which is affected by innovations from RMB ordinary shares (SHAI and SZAI) and foreign exchange markets (USD/RMB and HKD/RMB). The last two equations represent restrictions on exchange rate equations. This chapter assumes that the USD/RMB only responds to changes in the Shanghai foreign stock market (SHBI). For the HKD/RMB, it is subject to the shocks from the SZBI and USD/RMB, since foreign capital stocks in the Shenzhen stock market are traded in HKD, which receives shocks from the USD/RMB due to a linked exchange rate system in Hong Kong.

Lag length selection for the conventional SVAR model is based on the information criteria, which is the same lag length (1 lag) as selected in the multivariate Granger causality test.[55] The proposed restrictions in equation (3.11) are imposed on short run parameters, but the model results indicate the over identification of the SVAR model. However, the χ^2 of the likelihood ratio (LR) test cannot completely reject the null hypothesis.[56] The χ^2 equals 4.7 with a p-value of 0.095, which partially accepts the null. This means that short run restrictions in equation (3.11) are still valid.

Figure 3.3 represents structural innovations between exchange rate changes and shock returns. The shaded areas are the 95% confidence interval. It is evident that contemporaneous shocks from SHAI returns do not show any obvious impact on foreign exchange markets, but exhibit small effects on other stock markets (SHBI, SZBI and SZAI and HSI) at the onset of the shock, and these effects disappear in a short period. The confidence interval is extremely narrow for the SHAI shock, which suggest that there are no uncertainties in the SHAI shock. The second column represents the SHBI shock. Negative effects on foreign exchange markets with high volatility in structural parameters are demonstrated in the graph, but the shock on other stock markets from the SHBI tend to be positive and long-lasting, including the Shanghai, Shenzhen and Hong Kong stock markets. This might be due to the trading currency of the SHBI, which reflects the dominating position of the USD in the global economy and its influences on the Chinese financial market. The transmission channel could be: $USD/RMB \rightarrow SHBI \rightarrow$ other stock markets. The middle part of this figure shows the structural innovation from the Shenzhen stock market. The third column gives the SZAI shock, which has a positive impact on

[55] One lag included in the model is enough to "whiten" the error terms. The estimation process is very time consuming when 2 lags are included, which may take several days to converge.

[56] The null hypothesis for the LR test of identifying restrictions in the SVAR model is that any overidentifying restrictions are valid.

RMB ordinary shares and foreign capital shares in the Shenzhen stock exchange, but its effects on other markets (SHBI and two foreign exchange rates) are ambiguous and full of uncertainties. Column four gives the SZBI shock. It clearly demonstrates that SZBI shocks have negative effects for RMB ordinary shares, but positive effects for foreign capital shares and the HSI. However, the impact on foreign exchange rates are ambiguous since those estimated short run parameters cross the zero line.

The HSI shock is represented in column five of Figure 3.3. The SHBI and USD/RMB receive negative effects from the fluctuation of the HSI, but it seems that this is not a plausible conclusion since the RMB exchange rate is strictly monitored by authorities and the HSI usually does not exhibit too much influence on the foreign exchange rate of USD/RMB according to practitioners' experience. The remaining figures in column five show the ambiguity of HSI shocks. One feature reflected from these figures is that effects of the HSI shock on mainland stock markets have been strengthened since 1997.

The last two columns of Figure 3.3 show structural innovations from exchange rate changes in USD/RMB and HKD/RMB, respectively. Apparently, both structural shocks have negative effects on foreign exchange markets, but their influences on stock markets are ambiguous. The results are in accordance with the multivariate Granger causality test that exchange rate changes cannot Granger-cause stock returns. However, several shocks in Figure 3.3 have long durations and high uncertainties in short run parameters. Nevertheless, the overidentfication test of the conventional SVAR model only partially accepts the null hypothesis, which leads to the failure of interpreting some of the shocks of interest in the impulse response graphs.

3.5.3 Modelling Spillovers Using the MS-SVAR

3.5.3.1 Model Selection and Prior Specifications

This chapter includes one lag in the MS model, which is enough to ensure the stability of the VAR model based on the daily dataset. Another option about the MS model is the model restriction, which could be imposed on the state-dependent variance-covariance matrices. The state selection for the MS-SVAR model starts from two states, then subsequently increases states and changes restrictions. Table

3.4 reports log likelihood statistics and information criteria for different MS models. The unrestricted VAR and SVAR model do not present any indication of which model should be selected. The MS-SVAR model can be estimated using Dynare.[57] As shown in the table, panel A prefers three states MS model with switching in variances. Panel B indicates that two states with coefficients-switching in the MS model are desirable. Panel C demonstrates that three states with switching in variances are appropriate based on the sample of the post-crisis period.

All matrices in the MS model can be state-dependent: $A(s_t)y_{t-i} = F(s_t)x_{t-i} + \Xi^{-1}(s_t)\varepsilon_t$, for $1 \leq t \leq T$. x_{t-i} is a vector of lagged variables and Ξ^{-1} is a 7×7 diagonal matrix of standard deviations of ε_t. $F(s_t)$ is a matrix $[A_1(s_t)...A_p(s_t)C(st)]$. s_t is defined as h-state Markov process with a transition matrix $Q = (q_{i,j})$, where $q_{i,j}$ is transition probability that $s_t = i$ given $s_{t-1} = j(q_{i,j} \geq 0)$. The prior for SVAR parameters in this chapter is the six hyperparameters proposed by Sims and Zha (1998).[58] Following Sims and Zha (2006), the prior specification in this chapter is set as: $\mu_1 = 0.57, \mu_2 = 0.13, \mu_3 = 0.1, \mu_4 = 1.2, \mu_5 = 10$ and $\mu_6 = 10$. Each element of the diagonal matrix $\xi^2(s_t)$ is a γ distribution prior and parameters are set as $\bar{\alpha} = 1$ and $\bar{\beta} = 1$ in $\Gamma(\alpha, \beta)$ (Sims et al., 2008). The last prior on transition matrix Q is a Dirichlet distribution, which has unrestricted parameters $\alpha_{i,j}$ and restricted parameters β_{ij}. In the transition matrix Q, off-diagonal elements are set as one and diagonal elements are computed with $\alpha_{jj} = \frac{p_{j,dur(h-1)}}{1-p_{j,dur}}$. Where $p_{j,dur}$ is the average duration in the Markov chain.

3.5.3.2 Volatility Structure and Impulse Response Analysis

In the MS-SVAR model, the volatility structure is clearly demonstrated in the Markov chain with transition probabilities and the impulse response graphs. Figure 3.4 displays standardized residuals of the three MS-SVAR models. The plots

[57] Dynare is a software platform for dealing with a wide range of economic models, especially for the dynamic stochastic general equilibrium (DSGE) models.

[58] Six hyperparameters are imposed on the MS model to control the tightness of the prior. μ_1 controls the overall tightness of the random walk prior. μ_2 and μ_3 control the relative tightness of the random walk prior on lagged coefficients and the constant term, respectively. μ_4 controls the tightness of the prior that dampens the erratic sampling effects on lag coefficients. μ_5 controls the weight on the sum of coefficients in each equation through dummy observations with the constant term excluded. While μ_6 controls weight on a single dummy initial observation with constant included. Among these priors, the smaller of the value of μ_i for $(i = 1, ..., 4)$ indicate a tighter random walk prior, and the larger values for μ_5 and μ_6 suggest a tighter prior on unit roots and cointegration.

show that the model residuals are homogeneous although some of them demonstrate higher volatilities over time, which might be due to the high frequency data. The MS model with two or three states switching in coefficients or variances capture the dynamic structure of each equation, which is further discussed in transition probabilities. Two striking features can be drawn from these figures: (1) the residuals of stock returns present higher volatilities than exchange rate series in panel A and B, while both stock returns and the two exchange rates in panel C show strong volatilities; (2) long spikes appear in the residuals of USD/RMB and HKD/RMB in panel A and B around mid-2005, which might imply the impact of the 2005 RMB policy reform.

Transition probabilities among states are reported in Table 3.5. Clearly, each state has a high transition probability in maintaining its ongoing state, which is illustrated by diagonal elements of each matrix. The probabilities of state transformation between state 1 and state 2 are very low, specially in transferring from the high volatility to the low volatility. It is possible that the low volatility can change into a transition state (state 3), and vice versa, but the state transformation between the high volatility (state 1) and the transition state (state 3) will never occur in this case.

Figures 3.5-3.7 represent smoothed state probabilities of the three samples, respectively. Each MS-SVAR model has different switching states, referred as distressed state, normal state and transition state.[59] In Figure 3.5, three states depicted from the whole sample test capture the volatilities in foreign exchange markets and stock markets. Figure 3.5 gives separate states for panel A, which allows us to have a clear view on the dynamic structure of the Chinese financial market. State 1 is the normal state which captures tranquil periods from mid-2006 to early 2008, and from late 2010 to late 2012. State 2 indicates the distressed state (high volatility) which represents those periods of bear markets (mid-1995 to early 1996, May 1997 to May 1999, middle 2001 to middle 2005, the 2008-2009 world crisis). State 3 depicts the transition state, which means that there are no significant changes in the market. The transition state also indicates the instability and vulnerability of the Chinese financial market during the 1997 Asian financial crisis and the 2008 world financial

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

crisis. Figure 3.6 depicts smoothed probabilities for the subsample test spanning the period from July 1997 to the end of 2007. Distressed states can be demonstrated from the high volatility in mid-1997 and late 2007. The separate state 1 captures the distress time of the Chinese financial market from mid-1997 to mid-1999, although several tranquil periods appear during this period. State 1 also indicates the tough time in late 2007. While state 2 captures several tranquil periods and the relative long-lasting stable state starts from mid-2001 to late 2006. Figure 3.7 represents smoothed probabilities since the onset of the 2008 world financial crisis. Apparently, high volatility is depicted in state 1, which suggests that the Chinese financial market experienced difficult times in 2008, mid-2010 and mid-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 stage.

The impulse response functions for the three panels are given in Figures 3.8-3.10. These shocks with parameter uncertainty capture spillovers in the Chinese financial market. For panel A, 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 interval cross the zero line. The SHBI shock has a positive impact on stock markets but a negative impact on foreign exchange markets. Moreover, the SZAI is negatively correlated with the SHAI, SHBI and foreign exchange rate of HKD/RMB, but it exhibits positive effects on the returns of Shenzhen stock markets. In the Shenzhen stock market, the SZBI shock has negative effects for foreign capital shares but its influences on other markets are still ambiguous due to parameter uncertainty. With the strengthening of economic ties between Hong Kong and mainland China, the Shanghai and Shenzhen stock markets receive strong shocks from the Hong Kong market. One of the significant shocks is spillovers on the SHBI. The change in USD/RMB also has a negative impact on the SHBI, but positive effects are identified on foreign exchange markets. The last column of Figure 3.8 gives the HKD/RMB shock. The shocks from the SZBI are not as large as those shocks from the SHBI, which might be due to the linked exchange rate policy in Hong Kong.

The impulse response graphs for the two subsamples exhibit different structural innovations. The duration of shocks after the 1997 Asian financial crisis is about

10 days, while the shock lasts about 6 days in the sample of post-crisis period (the 2008 world financial crisis). Both are longer than the shock shown in the whole sample. In addition to the duration of shocks, the results from panel B and C show that the SHBI shock has positive effects on stock markets but a negative impact on foreign exchange markets. It is also evident that the duration of structural shocks on stock markets from foreign exchange markets are two periods longer than those on foreign exchange markets. This means that exchange rate changes have significant contemporaneous spillover effects on stock markets, although there are no long run spillovers on stock prices. This also suggests that the managed floating exchange rate policy helps to protect the Chinese economy from external shocks in the long run, but short run spillovers from exchange rate changes are still found to be significant.

3.6 Discussion

Motivated from the turmoils in foreign exchange markets and stock markets, this chapter empirically investigates spillover effects between exchange rate changes and stock returns in the Chinese financial market spanning the period from 1 January 1994 to 31 December 2012. Building upon the existing literature, this chapter is different from previous studies on the Chinese financial market mainly in three ways. First, in examining spillovers, the chapter takes into consideration both foreign capital shares (Shanghai B-share and Shenzhen B-share), RMB ordinary shares (Shanghai A-share and Shenzhen A-share), the HSI, as well as corresponding exchange rates of USD/RMB and HKD/RMB. While previous studies on the Chinese stock market neither incorporate both foreign capital shares and RMB ordinary shares into their analyses simultaneously, nor take into account the Hong Kong market (Bailey, 1994; Nieh and Yau, 2010; Tian and Ma, 2010; Zhao, 2010). Second, this chapter examines spillover effects during the 1997 Asian financial crisis and the 2008 world financial crisis, however, spillovers during the financial crisis are commonly ignored in the previous literature on the Chinese stock market. Finally, this chapter applies the multivariate VAR to examine the dynamic relationship between exchange rate changes and stock returns, and further tests contemporary shocks using the conventional SVAR model, and finally extends the model in a Markov structure, which captures volatile structures in the Chinese financial market.

The multivariate Granger causality test indicates that there is only a unidirectional relationship in the Chinese financial market, which is running from stock returns to exchange rate changes (see Table 3.3). The results show that RMB ordinary shares do not have any impact on foreign exchange markets ($SR_A \nRightarrow ER$), but spillover effects from Shanghai B-shares on other Chinese stock markets and foreign exchange markets are found to be statistically significant ($SR_{SHBI} \Rightarrow ER$ and $SR_{SHBI} \Rightarrow SR$). Although the existing literature suggests that stock returns are closely related to exchange rate changes, the results shown in this chapter reveal that exchange rate changes cannot Granger-cause stock returns ($ER \nRightarrow SR$). Interestingly, the SZBI shock has a significant impact on the Shanghai stock market ($SR_{SZBI} \Rightarrow SR_{Shanghai}$) as shown in Table 3.3. A possible reason for this could be the sensitivity of the Shanghai stock market and the sentiment of investors. Moreover, the HSI shock has a significant impact on the Shanghai stock market but does not exhibit any linkages with foreign exchange markets. These identified causal relationships are consistent with realities in China. On the one hand, the restriction on the daily floating range of the RMB exchange rate helps to protect the Chinese stock market. Any severe shocks to the RMB exchange rate market could be temporarily restrained. On the other hand, the fluctuation of stock returns have a significant impact on exchange rate changes, especially those shocks from Shanghai B-shares. This implies the importance of the Shanghai city as the national economic and financial centre, as well as the influence of the USD on the Chinese financial market.[60] Finally, the HSI exhibits some effects on the mainland Chinese stock market. this could be due to the increasing economic ties between the two markets.

In order to observe structure innovations, the conventional SVAR analysis is carried out in this chapter. To identify the SVAR model, this chapter does not impose triangular matrix restrictions, since no theoretical assumptions could support such restrictions for this case. In this chapter, short run restrictions in equation (3.11) based on theoretical assumptions and practical experiences are used to identify the SVAR. These restrictions are valid since the overidentifying test partially accepts the null hypothesis. However, the contemporaneous shock between exchange rate changes and stock returns from SVAR estimates are quite ambiguous. Added to that, the statistical validity of these short run restrictions cannot be examined and the identification is usually inadequate to explain certain shocks. These inefficiencies

[60] This might suggest that the RMB exchange rate is still mainly referred to the USD, although it is announced that the RMB exchange rate refers to a basket of currencies.

lead to the parsimonious output of the SVAR model.

To overcome drawbacks of the SVAR model, this chapter applies a Bayesian MS-SVAR model to investigate spillovers, which can be simply carried out by restricting the number of regimes and the switching parts (variances or coefficients) based on prior specifications suggested by Sims et al. (2008). Smoothed state probabilities from each sample reflect the distressed state, normal state and transition state of the Chinese financial market (see Figures 3.5-3.7). The high (low) volatility correspond to the tough (tranquil) period of the Chinese economy. While the transition state implies no obvious changes in market trends. For those impulse responses of MS-SVAR estimates, the SHBI shock has positive effects on stock markets but a negative impact on foreign exchange markets. The remaining shocks from stock markets (SHAI, SZAI, SZBI and HSI) or foreign exchange markets (USD/RMB and HKD/RMB) have mutual effects, but most effects are ambiguous due to high parameter uncertainty. Comparatively, the shocks from the subsample estimates have longer durations than those from the whole sample. This further confirms the existence of linkages between exchange rate changes and stock returns in China.

In general, the empirical suggests that in the long run exchange rate changes cannot Grange-cause stock returns, but stock returns affect exchange rates. This is due to the implementation of a managed floating exchange rate policy in China. As the Chinese financial market is far more than mature, the authorities have to insist on the current exchange rate policy in order to protect the vulnerable Chinese financial market against external shocks. The Hong Kong market has seen an increasing connection with the mainland stock market since the return of Hong Kong. The announcement of the merger of the Shanghai and Hong Kong stock exchanges further strengthen the link between the two markets. The VAR estimates reveal that USD has an significant impact on HKD because of the linked exchange rate policy adopted in Hong Kong. Although the RMB exchange rate policy shelters the Chinese financial market, there might be spillovers from the Hong Kong market, since Hong Kong is the global financial centre and the Hong Kong stock market is more volatile when receiving shocks from global financial market, ie, the appreciation/depreciation of the USD, the transmission channel could be: USD $\Rightarrow$ HKD $\Rightarrow$ HSI $\Rightarrow$ mainland stock market. Nonetheless, exchange rate changes have short run spillovers on stock returns according to the MS model estimates. The spillovers have longer durations during financial crisis periods. This might be due to the restriction on currency daily trading band in China. In the short run, exchange rate shocks have limited influence on stock returns in China. In the long run, the Chinese government keeps the RMB from instability by means of capital control, setting the RMB daily central parity rate, buying or selling USD in the foreign exchange market, etc. The results on the spillover effects between exchange rates and stock prices in the Chinese financial market presented in this chapter is consistent with the currency policy in China.

3.7 Conclusions

This chapter investigates spillover effects between exchange rate changes and stock returns in the Chinese financial market. The multivariate VAR model indicates that there is a unidirectional relationship running from stock markets to foreign exchange markets, but exchange rate changes cannot Granger-cause stock returns, which is due to the implementation of a managed floating exchange rate regime in China and a linked foreign exchange policy in Hong Kong. The shocks from foreign capital shares have significant influences on stock markets and foreign exchange markets, particularly the shock from Shanghai B-shares. Investors who are investing in RMB ordinary share markets and RMB foreign exchange markets could make appropriate adjustments according to the fluctuation of the SHBI. In addition, the conventional SVAR model together with restrictions on short run parameters are applied to test structural innovations. These restrictions are valid but the model estimates are inadequate to explain some of the shocks of interest. Further, the MS-SVAR model is introduced to investigate spillovers in the Chinese financial market, which allows coefficients and variances to be state-dependent. This model captures volatile structure of the Chinese financial market. The identified high (low) volatilities in smoothed probabilities are consistent with tough (tranquil) periods of the Chinese economy. A striking feature of impulse response functions is that the SHBI has positive effects on stocks markets but a negative impact on foreign exchange markets, which is consistent with identified causal relationships. Added to that, parameters represent more uncertainties during the 1997 Asian financial crisis and the 2008 world financial crisis. The estimates from the two subsamples also indicate that shocks have longer durations compared with the whole sample estimates. For practical implications, this chapter suggests that investors need to pay attention to the systematic risk from RMB policy changes due to the increasing pressure from the international community, which may alter the current unidirectional causal relationship in the Chinese financial market.

Appendix A: Multivariate VAR and Conventional SVAR model

Recap the multivariate VAR model:

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

Where $y_t = (y_{1t}, \cdots, y_{nt})'$ is a $n \times 1$ dimensional vector. D is the coefficient matrix of deterministic components d_t. A_i are $k \times k$ coefficient matrices for $i = 1, \cdots, p$ and u is k-element vector of error terms.

$$A_i = \begin{pmatrix} A_{i,11} & A_{2,12} & \ldots & A_{i,1n} \\ A_{i,21} & A_{i,22} & \ldots & A_{i,2n} \\ \vdots & \vdots & \ddots & \vdots \\ A_{i,n1} & A_{i,n2} & \ldots & A_{i,nn} \end{pmatrix}$$

Where $E(u_t) = 0$, $E(u_t u_t^{'}) = 0$ when $t \neq s$, and $E(u_t u_t^{'}) = \Sigma_u$ if $t = s$, but contemporaneous correlations may exist in the elements of u_t. Conventional causality test in the VAR model is based on a Wald test of lagged terms in matrices A_i. When the number of variables reduces to two, it becomes the bivariate Granger causality test.

Re-write the multivariate VAR model into a structural form, the typical A-B model is expressed as:

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

In the equation, y_t is 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 argument matrices. ε_t is a k-dimensional identity covariance matrix vector of structural innovations. The matrix may be normalized as $\Sigma\varepsilon = I_k$. When $A = I_k$ and $B = I_k$, that is B-model and A-model, respectively. According to equation (3.3) and (3.5), $u_t = A^{-1}B\varepsilon_t$, and $\Sigma_u = A^{-1}BB'A^{-1'}$. Therefore, the model has $k(k+1)/2$ equations. Since both A and B have k^2 elements, so a minimum of $2k^2 - \frac{1}{2}k(k+1)$ restrictions are needed to be imposed to identify matrices A and B. Normally, zero or unit restrictions are placed on these matrices. Suppose $k = 3$, then we need to impose at least

12 restrictions. If zero restrictions are placed on matrix A, it means that contemporaneous relationships exist amongst endogenous variables. Zero restrictions on matrix B indicate some shocks do not have immediate (temporary) effects on some variables. Both kinds of restrictions are called short run restrictions. However, it is not easy to find appropriate and acceptable restrictions on the model, and in fact the directly imposed restrictions are not necessary to identify structural innovations and impulse responses. Blanchard and Quah (1989) proposed a useful method to impose restrictions based on the total impact matrix:

$$\Xi_\infty = \sum_{i=0}^{\infty} \Theta_i = (I_k - A_1 - ... - A_p)^{-1} A^{-1} B$$

The matrix Ξ is the long run response to the orthogonalized shock. If zero restrictions are imposed on matrix Ξ, it implies that some shocks (structural innovations) do not have total long run effects.

Estimating a SVAR is directly minimising the negative of the log-likelihood:

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

The overidentification test of the SVAR can be conducted using a Likelihood Ratio (LR) test:

$$LR = T(logdet(\tilde{\Sigma_u^r}) - logdet(\tilde{\Sigma_u}))$$

Where $\tilde{\sum}_u$ is the reduced form of variance-covariance matrix and $\tilde{\sum}_u^r$ is the restricted structural form estimation.

Appendix B: Markov Switching Structural VAR Mode Inference

In the MS-SVAR model, the distribution of the error term u_t is assumed to depend on a Markov process and s_t is a discrete state process with $t = (0, \pm 1, \pm 2, ... \pm M)$ and the transition probabilities is: $p_{ij} = Pr(s_t = j | s_{t-1} = i), i, j = 1, ..., M$.

$$u_t | s_t \sim N(0, \Sigma_{s_t})$$

The covariance Σ_{s_t} in the above equation varies across regimes, and it is also consistent with properties of statistical data. Take two states as an example(M=2), $p = \begin{bmatrix} p_{00} & p_{01} \\ p_{10} & p_{11} \end{bmatrix}$. $P(s_t = 0|s_{t-1} = 0) = p_{00}$, so $P(s_t = 1|s_{t-1} = 0) = 1 - p_{00}$. $P(s_t = 1|s_{t-1} = 1) = p_{11}$, then $P(s_t = 0|s_{t-1} = 1) = 1 - p_{11}$. Hence, unconditional probabilities $p(s_t = 0) = (1 - p_{11})/(2 - p_{11} - p_{22})$ and $p(s_t = 1) = 1 - p(s_t = 0)$. When it comes to M-states, the MS structure becomes a model with mixed normal disturbance terms, $u_t = \begin{cases} N(0, \Sigma_1) & (p_{11}) \\ \vdots & \vdots \\ N(0, \Sigma_m) & (p_m) \end{cases}$. The identification of structural shocks in the MS model is based on the assumption that only the variance of shocks are orthogonal across states but there will be no effect on impulse response functions. In addition, temporary shocks will not change across sample periods (Lanne et al., 2010). As the error term $\varepsilon_t = B_t^{-1}$ determines structural shocks, so any restrictions on conventional SVAR inferred from theory models are testable and over-identified. When two or more sates exist in the shock, the covariance matrix can be decomposed as $\Sigma_i = B\Lambda_i B', i = 2, ..., M$. Restrictions can be imposed on diagonal matrices Λ_i. Lanne et al. (2010) have proposed a likelihood ratio (LR) test based on the asymptotic χ^2 distribution (with a degree of freedom $\frac{1}{2}Mk(k+1) - k^2 - (M-1)k$) to test the invariance of primal impact of the shocks across regimes. Another point on the decomposition matrix is the error structure ε_t, which can be an A-model when $B = I_k$, then $\Sigma_i = A^{-1}\Lambda_i^* A^{-1'}$ for $(i = 1, ..., M)$. The variance of diagonal covariance matrix Λ_i^* is helpful in interpreting the regimes. Previous studies have different identification strategies for the MS-SVAR model, such as the variation of parameters are allowed across regimes (Rubio-Ramirez et al., 2005) and restrictions on the error covariance matrix only (no MS process in other matrices) (Lanne et al., 2010). Generally, a SVAR model with markov switching in the regimes can be identified by imposing restrictions on the number of regimes m and the variance-covariance matrix of structural shocks but without any additional constraints on short run matrices A and B. This is a crucial advantage in the identification technique which draws out an unrestricted contemporaneous parameter matrix and short run impact matrix without priori restrictions on the system.

The Markov switching SVAR in this chapter is a Bayesian form and all matrices can be state-dependent:

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

Where Ξ is a diagonal matrix and s_t is defined as m-state Markov process with transition matrix $Q = q_{i,j}$ (the transition probabilities). We can also switch coefficients and variances separately, as equation (3.8) and equation (3.9) display.

ML estimation is usually used to estimate the MS-SVAR model. The log likelihood function for a M-state MS-VAR 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 as follows:

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

Where Y_{t-1} is a matrix with the past information up to time t. $\Sigma_1 = BB', \Sigma_i = B\Lambda_i B', i = 1, ..., M$. Residuals of the reduced form are expressed in u_t. According to the conditional density function, $Pr(s_t = j|Y_t) = Pr(s_t = i|Y_{t-1})f(y_t|s_t = j, Y_{t-1}) / \sum_{i=1}^{M} Pr(s_{t=i}|Y_{t-1})f(y_t|s_t = i, Y_{t-1}), i = 1, ..., M$. Restrictions imposed on the regime covariance matrix is to ensure the nonexistence of singular properties in matrices.

Table 3.1: Summary statistics

Panel A: Descriptive statistics of 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 of 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 are calculated according to equation (3.10).
2. *** denotes the rejection of the null hypothesis at the 1% level.
3. The normality test is carried out in the Ox programming package. Doornik and Hansen (2008) argue that the JB test (Jarque and Bera, 1987) has poor small sample properties; the skewness and kurtosis are not independently distributed, and the speed of sample kurtosis closes to normality very slow. Doornik and Hansen define the statistic as: $e_2 = z_1^2 + z_2^2 \sim \chi^2(2)$.
4. Q(36) is the 36th order of the Ljung-Box Q-statistics in levels.

Table 3.2: 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. Restrictions for the ADF and PP tests are a constant without trend.
2. Critical values for the ADF and PP tests are -3.43 at the 1% level, and all the test results reject the null hypothesis at the 1% level.
3. The number in parenthesis is the lag length, which is selected by the Bayesian information criterion (BIC) and Bartlett kernel bandwidth for the ADF and PP tests, respectively.

Table 3.3: Multivariate Granger causality test

	SHAI	SHBI	SZAI	SZBI	HSI	USD/RMB	HKD/RMB
Panel A: Test for 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 for 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 for 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 significance of each lagged parameter using the Wald test.
2. Numbers in parentheses are P-values.

Table 3.4: MS models selection

Model	logL_T	AIC	BIC
Panel A: Information criteria for the whole sample(01/01/1994-31/12/2012)			
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 coefficient	133712.513	-54.600	-54.533
2 states, switching variance	133712.513	-54.600	-54.533
3 states, all-change	124054.695	-50.58	-50.599
3 states, switching coefficient	136894.876	-55.893	-55.801
3 states, switching variance	**137273.818**	**-56.031**	**-55.883**
Panel B: Information criteria for the subsample (01/07/1997-31/12/2007)			
2 states, all-change	71018.512	-52.438	-52.342
2 states, switching coefficient	**78247.333**	**-57.773**	**-57.662**
2 states, switching variance	78262.776	-57.769	-57.612
3 states, unrestricted	71222.758	-52.581	-52.461
3 states, switching coefficient	72283.871	-53.354	-53.204
3 states, switching variance	72283.871	-53.323	-53.081
Panel C: Information criteria for the subsample (01/01/2008-31/12/2012)			
2 states, all-change	33632.550	-52.523	-52.346
2 states, switching coefficient	34794.682	-54.330	-54.124
2 states, switching variance	34547.171	-53.910	-53.619
3 states, all-change	33717.623	-52.639	-52.417
3 states, switching coefficient	34795.523	NA	NA
3 states, switching variance	**35066.098**	**-54.660**	**-54.213**

Notes:

1. NA indicates that the MS model cannot converge based on such restrictions.
2. The information criterion has the general form $C(\theta) = -2logL_T(\theta) + C_T \times dim$.
3. The bold text suggests the best MS model for each sample.

Table 3.5: Transition probabilities among states

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

Figure 3.1: Exchange rates and stock indexes

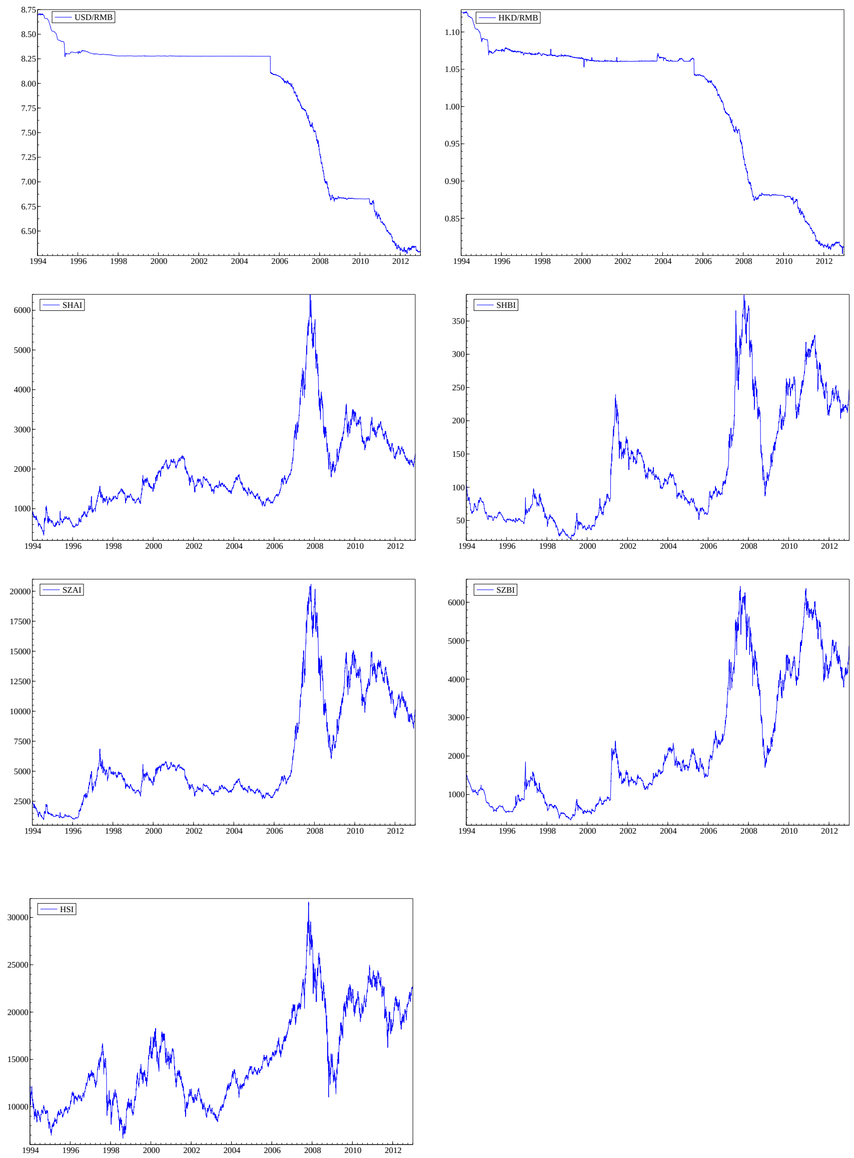


Figure 3.2: Exchange rate changes and stock returns

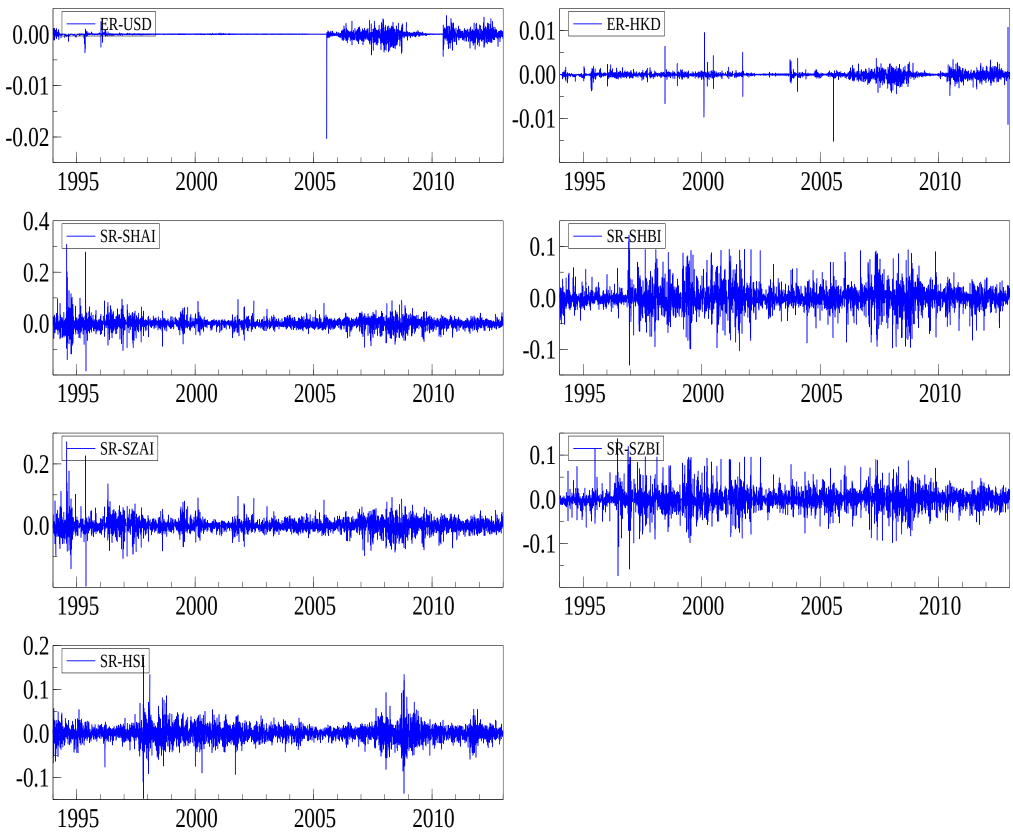


Figure 3.3: Structural shocks between exchange rate changes and stock returns

Figure 3.4: Standardized residuals of the MS-SVAR model

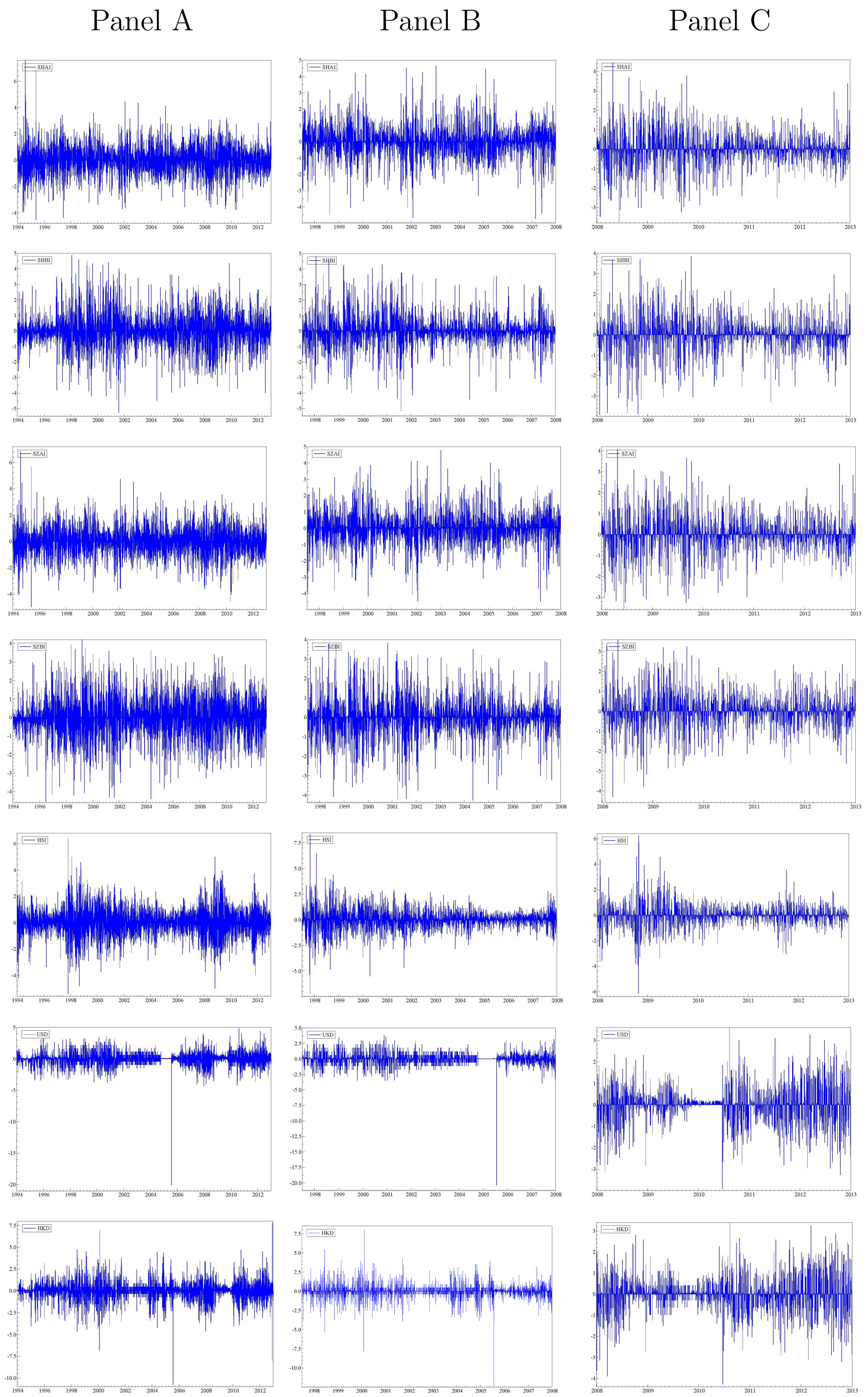


Figure 3.5: Smoothed state probabilities for panel A

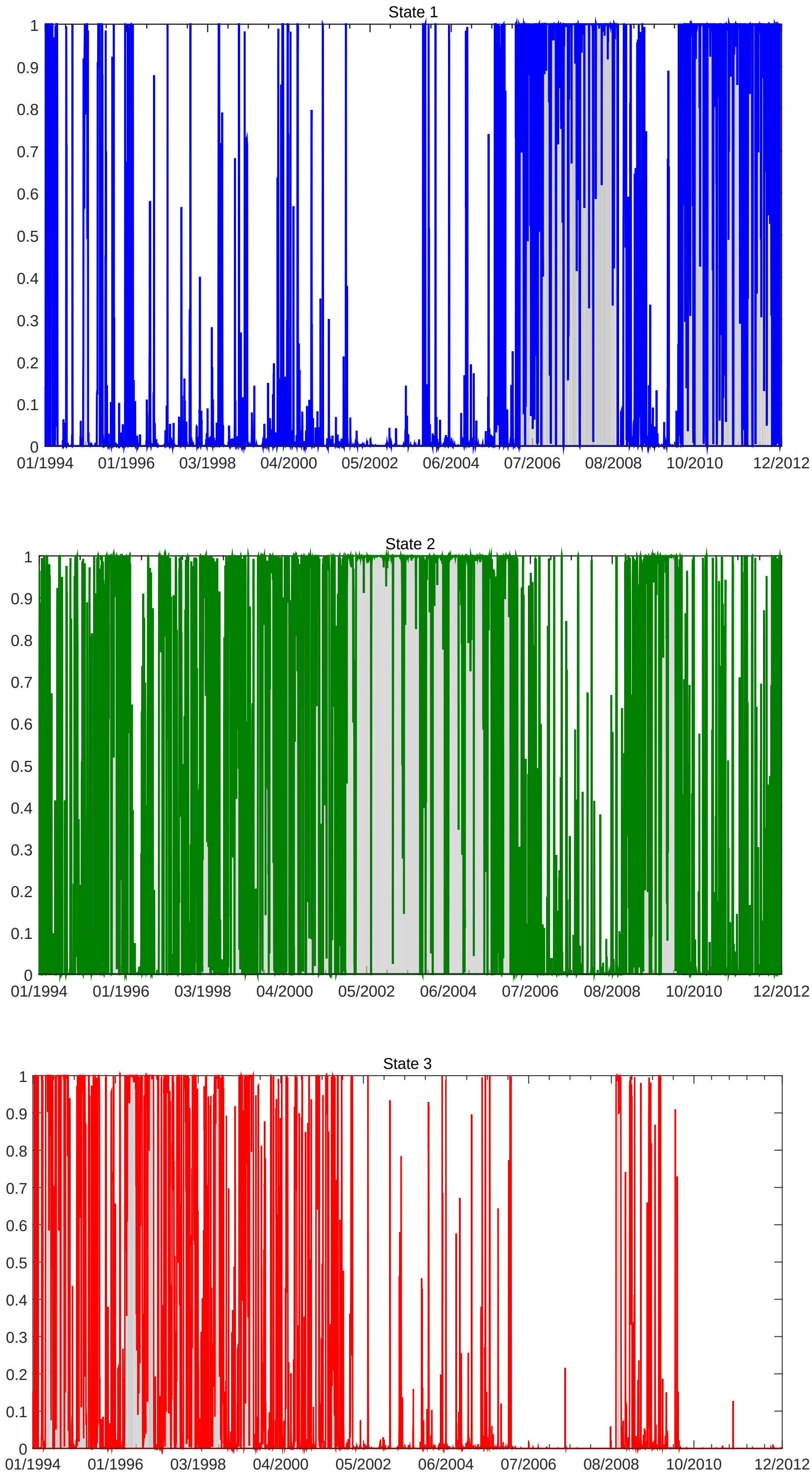


Figure 3.6: Smoothed state probabilities for panel B

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

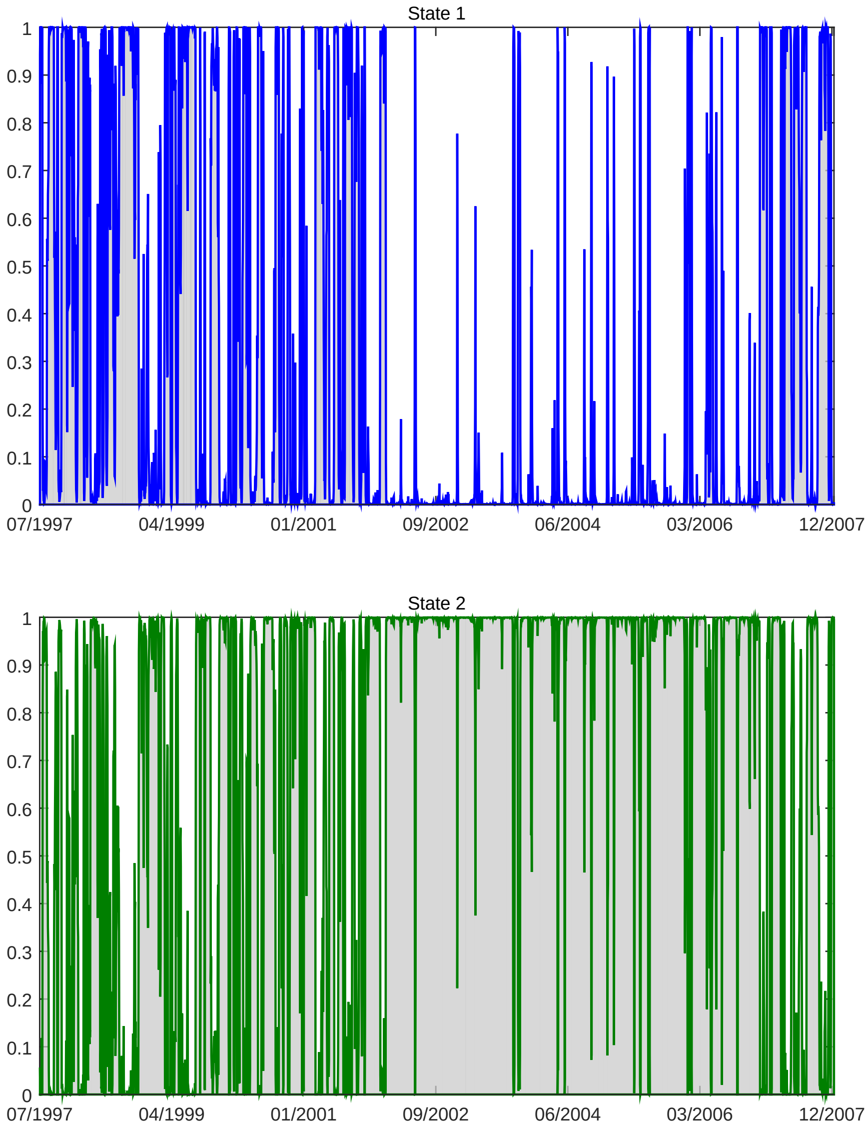


Figure 3.7: Smoothed state probabilities for panel C

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

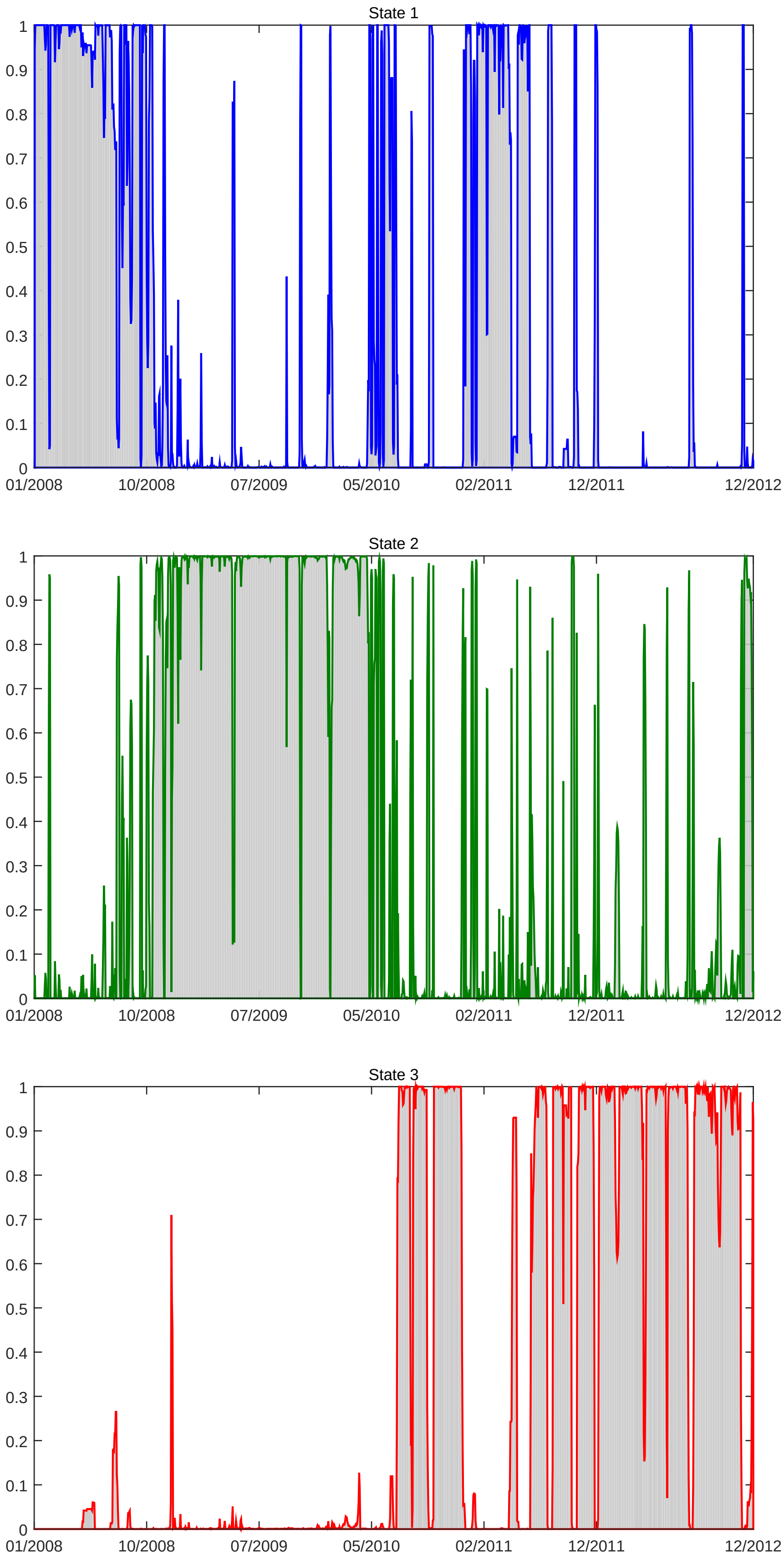


Figure 3.8: Impulse response functions for panel A

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

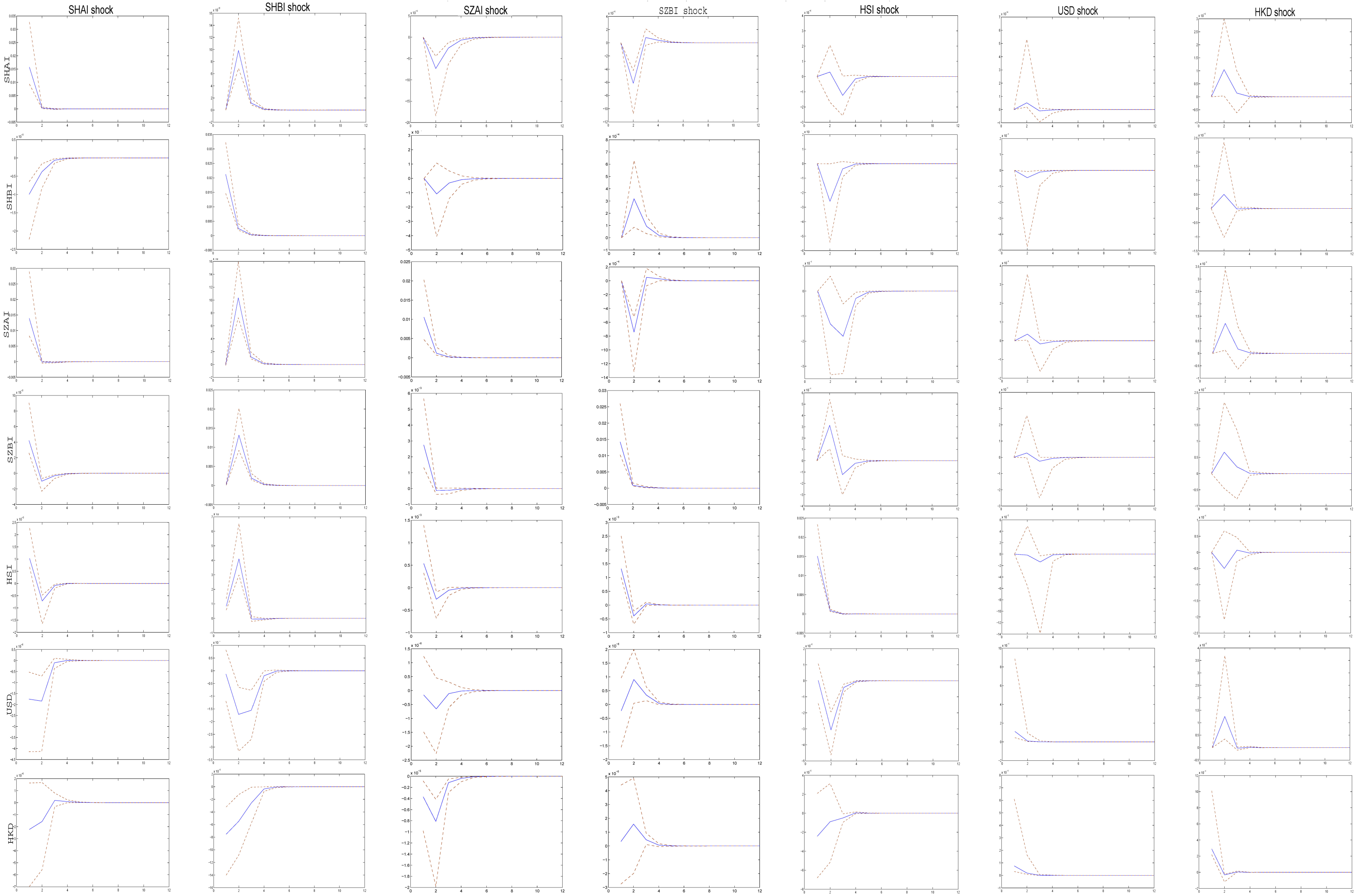


Figure 3.9: Impulse response functions for panel B

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

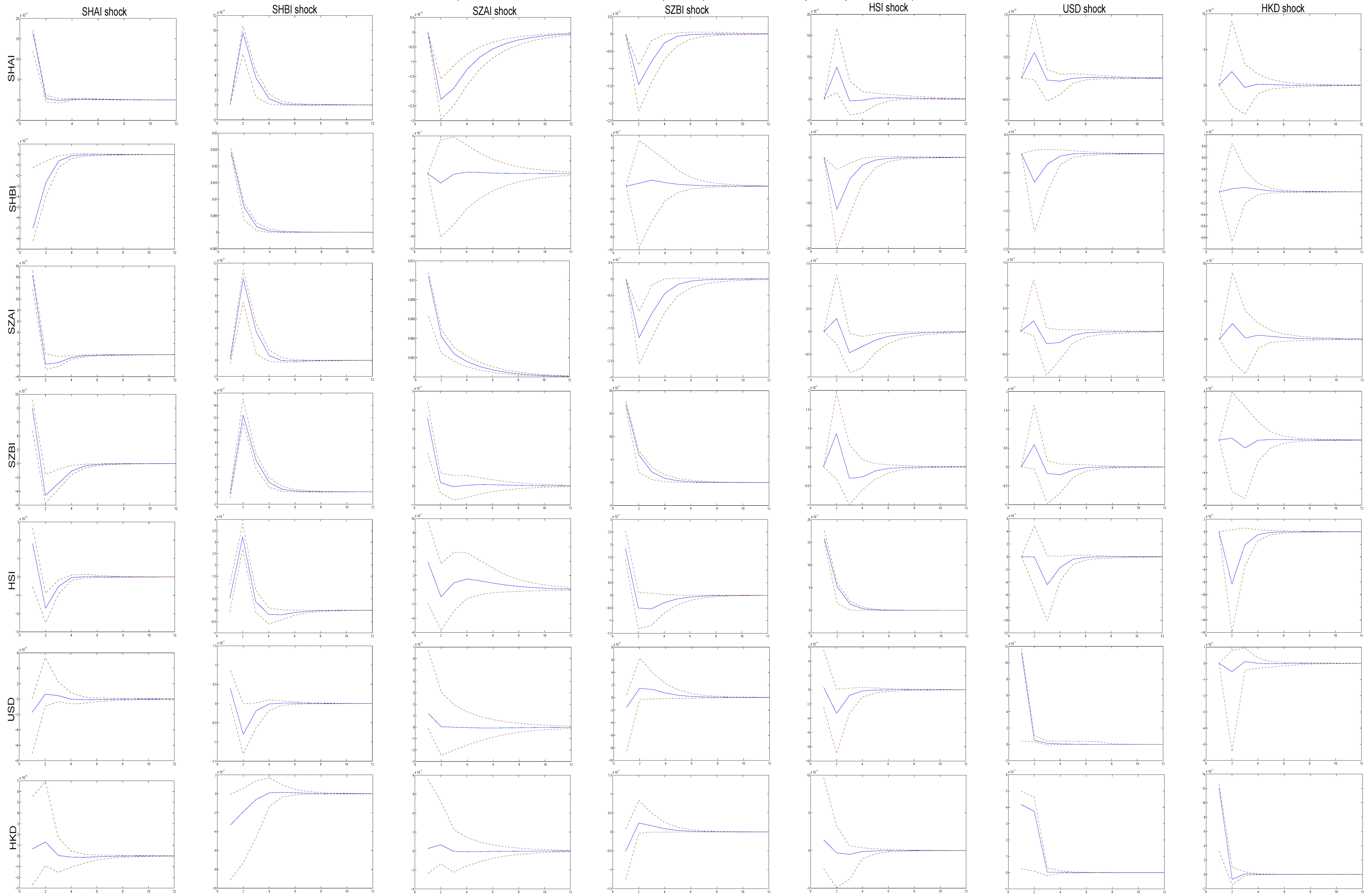
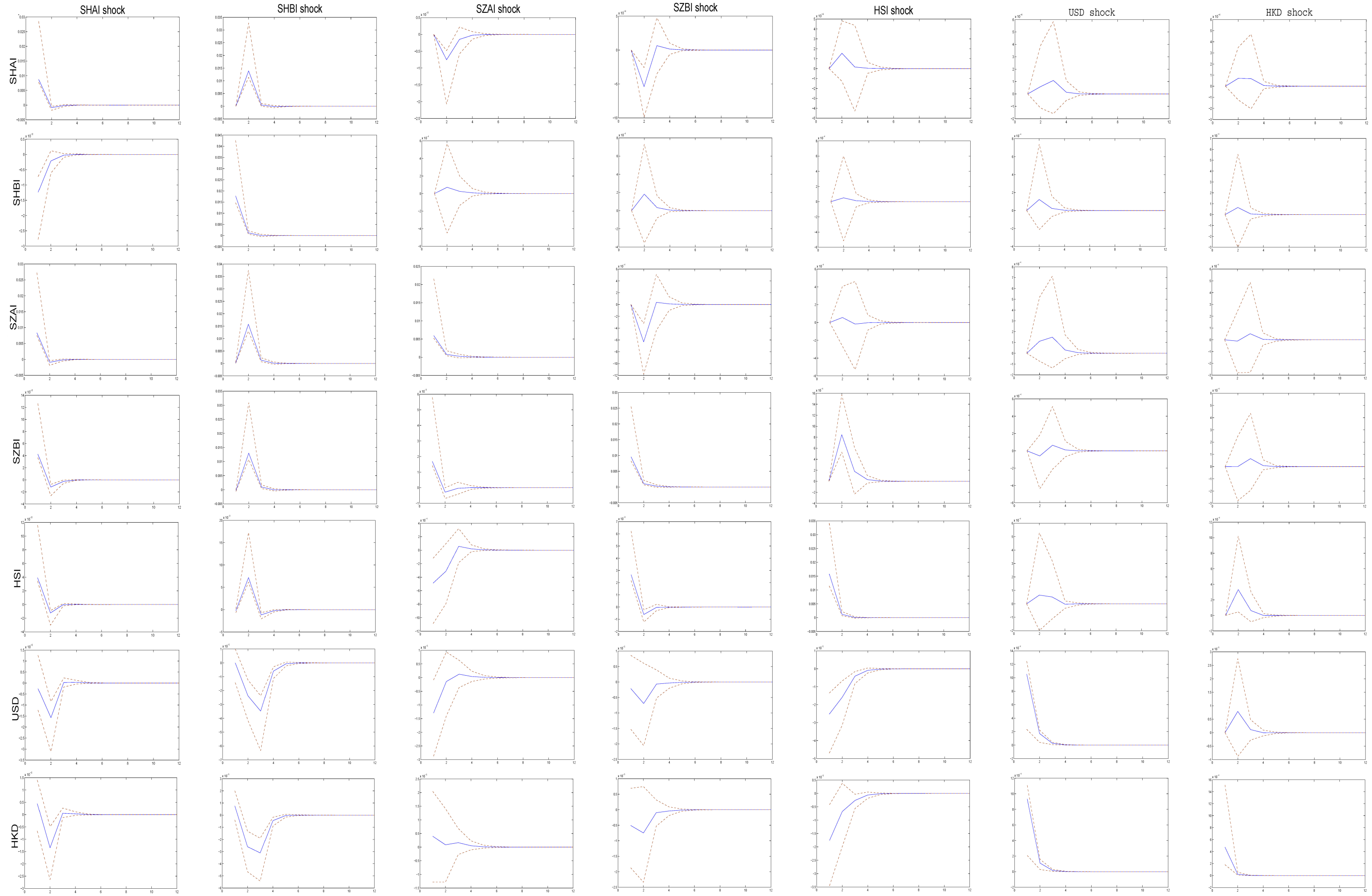


Figure 3.10: Impulse response functions for panel C

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



Chapter 4

Exchange Rate Exposure of Chinese Firms at the Industry and Firm Level

4.1 Introduction

In the era of financial integration, exchange rate changes have considerable influences on firm values during the transaction and operation process. The classical definition of exchange rate exposure refers to the influence of unanticipated changes in the exchange rate on firm values (Jorion, 1990; Madura, 2012). Multinational firms are subject to currency exposure by virtue of their global operations. Presumably, an economy would like to depreciate the currency to boost the domestic economy, but multinational firms that based on the economy may be subject to shocks from currency movements, as foreign income becomes less valuable than before. To effectively manage the exchange rate exposure, a firm should firstly identify the most influencing type of currency risk, then consider hedging strategies and available instruments to manage the currency risk. It is apparent that China has made great progress in its social and economic development with the implement of an opening door policy and a management floating exchange rate system. From trade partners' perspective, China has benefited from its currency system while trading with other economies, but that may have harmed trade partners' economies. Therefore the international community is keeping the pressure on RMB appreciation, which might have put Chinese firms in the situation of exchange rate exposure. However, the exposure management for Chinese firms are less than satisfactory. Most non-financial Chinese firms do not hedge the exposure from exchange rate changes since they lack understanding on the severity of the exchange rate exposure. It is apparent that a growing number of Chinese firms are actively financing in the financial market and expanding their business overseas. This raises the importance of managing currency risks with the ongoing but loosening managed floating exchange rate system in China. In response to the pressure from trade partners, Chinese authorities have to make some changes to its exchange rate policy, and this may further increase exposures to firm values. Given this background the aim of this chapter is to investigate exchange rate exposure of Chinese firms at both the industry and firm level, which might help firm managers deepen their understanding of currency exposure, so as to efficiently manage the exchange rate exposure in the near future. With the rise of China, an increasing number of studies are focusing on the Chinese currency system and its economy growth, but currency exposure studies in China are still very rare, specially for Chinese firms at the firm and industry level. Thus this chapter also contributes to the existing exchange rate risk literature on Chinese firms. Before the discussion of the exchange rate exposure of Chinese firms, several general issues about the exchange rate exposure definition, the foreign trade in China and the RMB exchange rate policy are introduced.

4.1.1 Exchange Rate Exposure Definition

In the context of economic liberalisation and globalisation, most multinational corporations have their primary location in one country but have production and sales operations in other countries. The majority of these multinational firms obtain raw materials from one country, financing from the international financial market, hire cheaper labour and produce goods in a third country and sell their products in the global market. These firms are no doubt exposed to exchange rate changes in the international market. The conventional exchange rate exposure theory indicates that firm returns are subject to changes in the exchange rate (Adler and Dumas, 1984; Jorion, 1990; Dominguez and Tesar, 2001). Existing studies have made a clear classification on the exchange rate exposure. Generally, three types of typical risks caused by changes in the exchange rate will affect firm values to a greater extent (Cuthbertson and Nitzsche, 2001; Hakala and Wystup, 2002; Shapiro, 2008):

- Transaction exposure. This is the most common risk faced by many multinational firms. The transaction exposure occurs when firms receive and make payments denominated in the form of foreign currencies. It is basically cash flow risk and deals with the impact of exchange rate changes on transactional account exposure associated with receivables, payables or repatriation of dividends. This kind of risk is inherently short run to medium run.

- Translation exposure. It is encountered by businesses with overseas assets, income streams and liabilities. Multinational firms are subject to translation exposure during the process of the consolidation of their financial statements, especially when they have branches overseas. Normally this type of risk is medium run to long run in essence.

- Operating exposure. It is also known as economic exposure. It concerns the exposure of the firm's present value of future operating cash flows caused by exchange rate changes, which is a long run effect in nature.

World economies welcome the openness of global market. Every economy is putting efforts in increasing its share of world exports to existing markets and discovering potential new markets. However, these cross-market interactions and business activities suffer from exchange rate changes which are encountered by all open economies. The Chinese economy is not an exception either. The fast expansion of China's exports might be protected by the managed floating exchange rate system, which might be subject to change due to the continuous pressure from trade partners. To investigate the exchange rate exposure of Chinese firms, it is imperative to get some preliminary impressions about China's foreign trade and the RMB exchange rate policy.

4.1.2 China's Foreign Trade and RMB Exchange Rate Policy

Before 1978, the planned economic system and international political environment was a serious impediment to the development of foreign trade in China. The reform and opening door policy in 1978 launched a new age and an accelerating pace of economic transition and led hundreds of millions of Chinese people out of poverty. The total value of China's foreign trade was merely $20.6 billion in 1978, which accounted for no more than 1% of the world total. After China jointed in the WTO in 2001, China's foreign trade experienced a dramatic growth. Since 2009, China has been the largest exporter and second largest importer in the world.[61] More than 200 countries and regions have trade connections with China. The major trade partners of China are the EU, US, Japan, and other BRICS partners (Brazil, Russia, India and South Africa) and the Association of Southeast Asian Nations (ASEAN),[62] but trade connections with most emerging markets and developing countries are increasing in the new century. Concerning the structure of China's foreign trade, China's exports

[61] For more details please see the General Administration of Customs of the People's Republic of China (www.customs.gov.cn) and the Embassy of the People's Republic of China in the United States of America (www.china-embassy.org/eng.).

[62] See the ASEAN members via the link: www.asean.org.

are mainly characterized by labour-intensive products from small and medium-sized enterprises. The exports of high-tech products just started growing since 2000. In addition, according to the report of the China Securities Regulatory Commission (CSRC), more than 2500 Chinese listed firms are actively participating in the financial market and around 60% of them are exporting firms. With the expansion of the opening door policy, an increasing number of Chinese firms are seeking opportunities of doing businesses overseas. In the environment of economic globalization, these Chinese firms are subject to exchange rate exposure. This stimulates the author's interest in investigating the evidence of whether the RMB foreign exchange policy help to reduce the exchange rate exposure of Chinese firms.

The Chinese currency policy has undergone dramatic changes after the foundation of new China. In 1994, the dual system of foreign exchange markets was merged and the authorities launched the unified exchange rates policy. The daily floating range of RMB against USD was restricted at 0.3%. It means that the trading rate of RMB against USD in the interbank spot foreign exchange market was restricted to float within 0.3% based on the central parity rate announced by the People's Bank of China (PBOC) every trading day. The managed floating exchange rate system was implemented in China in July 2005. Since then, the RMB foreign exchange rate referred to a basket of currencies, not pegged to USD any more. In response to the pressure from trade partners, Chinese authorities have to make some changes to the currency system. The floating range was expanded to 0.5% in 2007 and was further widened to 1% in 2012. In March 2014, the daily floating range of RMB against USD was expanded to 2%.[63] Whether firm returns suffer from exchange rate exposure under the managed floating exchange rate system is one of the interests of this chapter.

4.1.3 Research Questions and Framework of this Chapter

The classical exchange rate exposure theory suggests that firm values and profitability are exposed to unanticipated changes in exchange rates (Shapiro, 1975; Adler and Dumas, 1984; Jorion, 1990; Cuthbertson and Nitzsche, 2001; Hakala and Wystup,

[63] Mr Deng Xianhong, vice Chairman of the State Administration of Foreign Exchange of China (SAFE), gave a keynote speech of the "Chinese Foreign Exchange Policies" on the international conference on "China After 35 Years of Economic Transition" on 8-9th May 2014 in London. More detailed Chinese currency policies can be found from the official web site of the PBOC and the SAFE.

2002). The empirical literature on the exchange rate exposure of firm or industry returns has seen a dramatic increase in recent years (Bodnar and Marston, 2002; Doukas et al., 2003; Muller and Verschoor, 2006; Chue and Cook, 2008). However, the studies on the foreign exchange exposure of Chinese firms are still scarce and also lack empirical evidence, particularly the exchange rate exposure of Chinese firms at both the industry and firm levels. Inspired from the existing research evidence and the background in China, this chapter aims to answer the following questions: (1) Do Chinese firms suffer from exchange rate exposure under the managed floating exchange rate system? If yes, which kind of exchange rate movement has the largest influence on Chinese firms? (2) Based on the conventional exchange rate exposure measurement framework, which approaches fit with the industry and firm level exposure analyses? Do they have different implications? (3) Are there any nexus between firm size and the exchange rate exposure? (4) Do lagged exchange rate changes have significant exposure effects on firm returns? With the rise of China and increasing interactions with the world economy, Chinese firms have close ties with the global market. The exploitation of the exchange rate exposure of Chinese firms has important theoretical and practical significance.

The exchange rate exposure of Chinese firms in this chapter is investigated from the following aspects. First, the capital market approach and the cash flow approach are applied to measure the exchange rate exposure of Chinese firms at the industry and firm level separately, which are estimated using a macroeconometric approach and a microeconometric approach, respectively. Second, exposure effects from different types of exchange rates are examined individually in order to determine which one has the largest influence on firm and industry returns. Third, three types of models based on the capital asset pricing model (CAPM) framework are estimated separately to identify the model of best fit . Fourth, the firm level exposure is estimated through the examination of size effects of different types of firms (large, medium and small firms) using the seemingly unrelated regression (SUR) approach. Exposure effects from lagged exchange rate fluctuations are also examined.

The remaining parts of this chapter are constructed as follows. Section 4.2 reviews empirical models for the exchange rate exposure measurement. Theoretical models and econometric strategies are discussed in section 4.3. Data and preliminary statistics are given in section 4.4. Section 4.5 details the exchange rate exposure measurement at the industry and firm level. Section 4.6 gives the discussion and last section concludes.

4.2 Exchange Rate Exposure Measurement

Most non-financial firms may have corporate treasuries or risk committees to manage the exchange rate exposure in industrial countries, specially those multinational firms (Lam, 2014). These special commissions specialise in analysing and managing market risks, but it is still not easy to measure the exchange rate exposure in a simple way, at least relating to the translation and operating exposure (Holton, 2003; Papaioannou, 2006). Currently, the widely used approaches are the Value-at-Risk (VaR) model, the capital market approach and the cash flow approach. There are also some theoretical models designed by researchers based on different contexts, which might be linear, nonlinear, symmetric or asymmetric models. Different approaches for measuring exchange rate exposure fit with different data sets and theoretical assumptions. Empirical model for measuring exchange rate exposure should take different realities into consideration, but the priority is to recognise advantages and disadvantages of these models.

4.2.1 Value at Risk (VaR)

The VaR approach is a statistical exercise for measuring the exchange rate exposure caused by firm activities (Holton, 2003; Alexander, 2009). It is an approach based on historical data of financial institutions and widely used in estimating the highest possible loss of asset values or returns within a specific time period at a given statistical confidence level, normally 95% (Papaioannou, 2006; Crotty, 2009). Jorion (1996) define the VaR as the relative loss of the asset to what was expected. The general form of VaR is expressed as follows:

$$\begin{aligned} VaR &= E(W) - W^* \\ &= W_0(\mu - R^*) \end{aligned} \tag{4.1}$$

In the above equation, W^* is the lowest portfolio value at a given confidence level. The calculation of VaR is to identify the minimum value of W^*, or the cutoff rate of return R^*. Three parameters are determined by the VaR approach: the holding period, the confidence level and the currency unit for denominating the VaR. The commonly used models for calculating the VaR are the historical simulation, the variance-covariance model and the Monte Carlo simulation. The three models have different assumptions on variable distributions. The historical and current currency returns on the firm's exchange rate position are assumed to have the same distribution. While the variance-covariance model is based on the assumption of normal distribution of currency returns on the firm's exchange rate exposure, as well as a linear relationship between exchange rate exposure and currency returns. Additionally, the Monte Carlo simulation assumes that currency returns are completely randomly distributed in the future.

In practice, the three models for calculating the VaR have their inherent drawbacks (Papaioannou, 2006; Crotty, 2009). The historical approach requires a large data set and intensive computation, but no historical data can be used to simulate a reliable currency exposure measurement. The variance-covariance model has a restrictive assumption on the normally distributed currency returns and the linear combination of the total exchange rate exposure, which are usually not the case. Random sampling is the key advantage of the Monte Carlo simulation, but it is an intensive computation process. Blankfein (2009) also suggests that another drawback of the VaR approach is the non-covering of foreign currency credited in the balance sheet.

The VaR approach is widely used in managing financial risks in empirical studies. As the risk management for financial institutions is intrinsically related to the VaR in a given financial position, Mittnik and Paolella (2000) apply out of sample predictions from VaR calculations to examine the predictive performance of three different ARCH models. However, the accuracy of VaR calculations is widely questioned and explored. Jorion (1996) suggests that the indispensable tool of the VaR approach in managing financial risks has some limitations, and the accuracy of VaR calculations can be improved through statistical methods such as the analysis of the estimation error in the VaR. Empirically, Berkowitz and Obrien (2002) have a detailed analysis on the performance of trading risk models through the examination of statistical accuracy of the VaR prediction based on the evidence of US commercial banks. Their findings show that the VaR approach is less useful as a measure of actual portfolio risk since the conservative estimates indicate higher levels of capital coverage for trading risk.

4.2.2 Capital Market Approach

Existing studies carry on the exchange rate exposure measurement based on the framework of Capital Asset Pricing Model (CAMP) (Adler and Dumas, 1984; Jorion, 1990; Dominguez and Tesar, 2001, 2006; Hsin et al., 2007; Chue and Cook, 2008; Du and Hu, 2012). One of the specific forms is the capital market approach, which explains that the exchange rate exposure is a priced factor. It means that the exchange rate exposure could theoretically be priced in an arbitrage pricing theory framework. The test of exchange rate exposure is including the variable of exchange rate changes on the right-hand-side of the conventional CAPM, and testing the significance of the exposure beta (Adler and Dumas, 1984). The standard two-factor CAPM regression has the following expression:

$$R_j = \alpha_j + \delta_j XR + \varepsilon_j \tag{4.2}$$

Where R_j is firm returns and XR denotes changes in exchange rates. δ_j is the elasticity of firm returns to changes in the exchange rate. It is called *total exposure elasticity*. This equation estimates the capital market exposure to changes in the bilateral or the trade-weighted effective exchange rate. Some control variables can also be incorporated in the model to remove the macroeconomic impact, such as market returns, and then the exposure coefficient is referred to *residual exposure elasticity*. The capital market approach is generally the regression of firm returns on a group of independent variables in which the exchange rate is compulsory and commonly used in testing the degree of exchange rate exposure. Among those empirical studies, there is another type of capital market approach, which takes the risk-free rate into account (Hsin et al., 2007; Huffman et al., 2010; Du and Hu, 2012). At both side of the CAPM, the firm returns and market portfolios are expressed in excess returns, since investors' expected returns should be higher than the risk-free rate.[64]

The capital market approach for measuring exchange rate exposure is extremely popular with researchers. Based on the capital market approach, existing studies have investigated the exchange rate exposure using specific firm-level data. Huffman

[64] In the CAPM, it is usual to incorporate excess returns (over and above the risk-free rate). This section is recapping the version of the capital market approach for measuring exchange rate exposure, which according to Adler and Dumas (1984) does not incorporate excess returns, then will move to the recent popular approach for measuring exchange rate exposure.

et al. (2010) explore the foreign exchange exposure of US manufacturing firms using Fama and French (1993)'s three-factor model, which exhibits significant coefficients compared with the traditional market model. Their results suggest that firm size is an important factor for interpreting exchange rate exposure. The degree of Asian firms exposed to the change in the US dollar (25%) is a little higher than the Japanese yen (22.5%) (Muller and Verschoor, 2007). There is a negative relationship between the foreign exchange rate of Asian currency against foreign currencies and share returns. The liquidity positions of firms will also determine the magnitude of exposure to a certain extent. Bodnar and Marston (2002) have also found a strong relationship between firm size and exchange rate exposure of US firms. In their model, the return horizon and market returns have a significant impact on exchange rate exposure estimates. Although the lagged exposure is relatively important to the short term exposure, Hsin et al. (2007) argue that lagged exposures cannot raise the significance of exchange rate exposure regarding the pricing for the whole sample shock, and priced currency risk of large firms specifically contribute to hedging activities. However, Du and Hu (2012) find that short term exchange rate changes are not priced in the American stock market based on the firm-specific exchange rate exposure analysis.

There is also a literature based on industry level data applying time series models, which investigate the exchange rate exposure from a macro perspective. Jorion (1991) indicates that the exchange rate exposure of US firms differ across industries and the exposure is not priced in the stock market. The traditional approach is inadequate in capturing the exchange rate exposure, the bivariate Glosten-Jagannathan-Runkle GARCH-Mean model is more efficient in investigating exchange rate risk (Jayasinghe and Tsui, 2008), since it explores four types of exchange rate exposures based on the case of Japan, namely the sensitivity of stock returns to exchange rate changes and the volatility of exchange rate changes, sensitivity of conditional variance of stock returns to exchange rate changes, and the dynamic conditional correlation between stock returns and changes in the exchange rate. Moreover, Dominguez and Tesar (2001) show that the exchange rate exposure will not decline over time according to both the firm-level and industry-level data analysis. Even where financial markets are increasingly becoming integrated, significant differences of exposure effects to firm, industry and country-level data still exist. However, Dominguez and Tesar (2006) have different explanations about exchange rate changes and firm values. They claim that firms do expose to exchange rate changes but the direction of exposure varies over time, since it is determined by the specific foreign exchange rate. And normally at the industry level, the exchange rate exposure is associated with a group of firm characteristics, such as firm size, overseas business, global assets and competitiveness.

4.2.3 Cash Flow Approach

The cash flow approach is an alternative approach for measuring exchange rate exposure in addition to the conventional two or three-factor capital market approach. The major difference between the traditional capital market approach and the cash flow approach is the left-hand-side variable. The former approach for exposure measurement is the regression of firm returns on exchange rate changes while the latter dependent variable is the cash flow. Putting the model in a simple way, the exchange rate exposure of total (or net) cash flows and firm values (stock prices) are identical (Bodnar and Marston, 2002; Bartram, 2007), as the current value of future cash flows of firms are interpreted by stock prices. In Bodnar and Marston (2002)'s paper, the exposure of stock prices and cash flows to exchange rate changes are assumed to be the same. The relationship can be expressed as: $\frac{d\ln V}{d\ln S} = \frac{d\ln CF}{d\ln S}$, where V represents firm value or stock prices, CF is cash flow and S is the exchange rate. The operating income is usually used as a proxy of cash inflows in empirical studies (Martin and Mauer, 2003a,b). In their papers, the sensitivity of operating incomes to exchange rate changes is expressed as:

$$UI_{it} = c_i + \sum_{q=0}^{L_i} w_i(q)X_{t-q} + u_{it} \tag{4.3}$$

Where UI_{it} is the operating income for firm i at time period t, and X_{t-q} is the change in the exchange rate. $w_i(q)$ is the exposure beta, which capture the sensitivity of cash flows to long run and short run exchange rate changes.

The exchange rate exposure studies using the cash flow approach are not as many as those applying the capital market approach, but the findings from the cash flow approach studies still have a far-reaching research influence. Bartram (2007) finds that exchange rate exposure of US non-financial firms is significant using the cash flow approach, particularly at longer horizons. Although the degree of exposures will increase with the length of the time horizon, the difference between the stock price exposure and the cash flow exposure is small. Similar results have been found in the paper of Martin and Mauer (2003a), who suggest that the exchange rate exposure at longer horizons are more prevalent than those from short horizons based on the sample of US banks. They also represent that domestic banks are more likely to be exposed to currency risk and the indirect effect of exchange rate exposure must be concerned. Under the framework of the cash flow approach, Martin and Mauer (2003b) introduce mean absolute response coefficients (MARCs) to measure the transaction and economic exposure. Comparatively, the transaction exposure is easier to evaluate and hedge than the economic exposure. The long term lags have larger cash flow effects than short term lags in the examined exchange rate exposure. This is consistent with other exposure studies in differentiating the degree of exposure from different time horizon estimates, as the exchange rate exposure is natural both in the short term and the long term (Chow et al., 1997).

4.2.4 Other Approaches for Measuring Exposure

In reality, there is no universal approach for measuring exchange rate exposure. The conventional approach for estimating exchange rate exposure is a linear regression of firm values (or cash flows) on a group of macroeconomic factors, in which changes in the bilateral (or trade-weighted) exchange rate are included [65] (Adler and Dumas, 1984; Dominguez and Tesar, 2001; Bodnar and Marston, 2002; Doukas et al., 2003; Bartram, 2007; Chue and Cook, 2008; Huffman et al., 2010; Du and Hu, 2012). However, the relationship between firm values and exchange rate changes may be nonlinear. The market portfolio variable added in the exposure measurement equation may be uncorrelated with exchange rate changes.[66] During currency appreciation-depreciation cycles, the exchange rate exposure might be asymmetric. Koutmos and Martin (2003) find that asymmetric exposure effects are more pronounced in financial and non-cyclical sectors. There are more studies on the investigation of exchange rate exposures applying nonlinear models. Priestley and Ødegaard (2007) extend the model by incorporating some macroeconomic variables. The exposure to exchange rate changes has been proved to be statistically

[65] In the foreign exchange market, many factors can affect the exchange rate, such as interest rate, inflation, market speculation behaviours and the nation's exchange rate policy.

[66] Under the framework of the CAPM, the expected risk premium on a firm's stock price is proportional to its covariance with returns of the market portfolio. Plenty of studies have incorporated market returns on the right-hand-side of the exchange rate exposure equation, such as the paper of Jorion (1990), Bodnar and Marston (2002) and Huffman et al. (2010).

and economically significant based on the nonlinear framework. Interestingly, the exposure to the change in the bilateral exchange rate is significant but the exposure to the change in the trade-weighted rate generates little evidence. Another nonlinear approach introduced by Bartram (2004) for estimating exchange rate exposures allows for asymmetry, which means that both positive and negative currency shocks can be captured by the model. The investigation of nonlinear exposure hypothesis is a piece-wise regression model which accommodates asymmetry. This approach identifies the existence of significant linear and nonlinear exposure to bilateral and multilateral exchange rates based on the sample of German firms. Using a conceptual approach, Flood Jr and Lessard (1986) argue that the market structure will determine the operating exposure, which is not related to physical assets of firms, and the information of financial statements is insufficient to assess firms' operating exposure. It can be actually understood from the competitive perspective of market structure. Moreover, a simultaneous structural model has been built by Dekle and Ryoo (2007) to estimate the exposure of Japanese industries. They find that exports volumes and financial constraints are major factors influencing the exposure of exports, and the fewer financial constraints faced by firms, the lower of the degree of exchange rate exposure.

4.3 Theoretical Models and Econometric Strategies

Exchange rate exposures have been examined under the CAPM framework for decades (Jorion, 1990; Bodnar and Marston, 2002; Dominguez and Tesar, 2001, 2006; Bartram, 2004; Chue and Cook, 2008; Du and Hu, 2012). The common used approach for estimating the CAPM is the ordinary least square (OLS). The measurement of exchange rate exposure is to estimate the coefficients for the change in exchange rates and other macroeconomic indicators. This chapter follows the conventional CAPM framework but introduces different techniques for estimating exposures.

4.3.1 Theoretical models and Assumptions

The conventional two-factor CAPM framework for measuring the sensitivity of firm values to the fluctuation of exchange rates has been widely applied in previous studies (Adler and Dumas, 1984; Jorion, 1990; Kiymaz, 2003; Bodnar and Wong, 2003).

The estimation of the exchange rate exposure is the regression of the fluctuation of firm values on exchange rate changes.

$$R_{j,t} = \beta_{0,j} + \beta_{1,j} ER_t + \varepsilon_{j,t} \tag{4.4}$$

Where $R_{j,t}$ is the rate of return for firm j (or industry j), ER is the log return of the exchange rate. If the changes in firm returns and exchange rates are totally unanticipated, the two-factor model is appropriate (Jorion, 1990), and $\beta_{1,j}$ is called total exposure elasticity. However, the other non-exchange-rate related effects are correlated with the exchange rate variable over the sample period. These "macroeconomic" conditions that influence the value of firms could be the change in the risk-free rate, the market portfolio and investors' sentiment. To control for other macroeconomic effects on firm returns, the existing literature incorporates the return of the market portfolio into the above model. The market return not only controls for macroeconomic effects but also dramatically reduces the residual variance of the model compared with equation (4.4). Also, building upon the CAPM, the expected risk premium on firm values is proportional to its covariance with the return of a market portfolio. In addition to the two-factor model, the augmented model takes the market return into account (Bodnar and Gentry, 1993; Dominguez and Tesar, 2001; Muller and Verschoor, 2006, 2007; Huffman et al., 2010).

$$R_{j,t} = \beta_{0,j} + \beta_{1,j} ER_t + \beta_{2,j} RM_t + \varepsilon_{j,t} \tag{4.5}$$

Where $\beta_{2,j}$ denotes the sensitivity of firm returns (or industry returns) to changes in the market portfolio RM_t. The exposure coefficient$\beta_{1,j}$ measures the exchange rate exposure elasticity of a firm as the difference between the firm's total exposure elasticity and the market's elasticity by the firm's stock prices. This is called residual exposure elasticity. This is different with the total exposure elasticity whenever market returns have a nonzero effect on the exchange rate. Fama and French (1993) consider the excess return of firm values by subtracting the risk-free rate. The excess return of firm values has been introduced to effectively measure the exchange rate exposure in existing studies (Hsin et al., 2007; Huffman et al., 2010; Du and Hu, 2012).

$$(R_{j,t} - RF_t) = \beta_{0,j} + \beta_{1,j} ER_t + \beta_{3,j} (RM_t - RF_t) + \varepsilon_{j,t} \tag{4.6}$$

In equation (4.6), RF_t is the risk-free rate. $(R_{j,t} - RF_t)$ and $(RM_t - RF_t)$ represent the excess return of firm j (or industry j) and the market portfolio, respectively.

For the industry level exposure measurement, $R_{j,t}$ is the industry return. The 7-day Treasury bills rate will be used as the risk-free rate RF_t. The nominal exchange rate affects firm values since their assets and liabilities have to be translated at the nominal rate. In terms of the translation of foreign assets, the nominal rate will be offset by price levels, therefore it cannot affect the firm real values. It is the real exchange rate that determines firm values (Williamson, 2001). The existing literature prefers to use the trade-weighted exchange rate to measure the exchange rate exposure, but it is still problematic, because the estimates may lack power when the nature of firm (or industry) exposure does not respond to the exchange rate of the trade-weighted basket of currencies (Dominguez and Tesar, 2001). This chapter assumes that firms and industries are exposed to different types of exchange rates. Three kinds of exchange rate will be examined in turn in this chapter, namely the bilateral normal exchange rate (NER) of USD/RMB, the real exchange rate (RER) of USD/RMB and the trade-weighted effective exchange rate (TWEER). The exchange rate exposure measurement of Chinese firms at the industry level is based on the following assumptions:

- **Hypothesis 1**: H0: Equations (4.4)-(4.6) have their advantages in measuring the exchange rate exposure, hence the best model should be determined by the empirical results; H1: only the three-factor model (equation (4.5)) is more efficient for the exchange rate exposure measurement.[67]

- **Hypothesis 2**: H0: Chinese firms (or industries) may be subject to the changes in the NER, RER and TWEER; H1: Chinese firms (or industries) are more likely to be exposed to the change in the TWEER.

These assumptions above are applied to both the industry and firm level data analysis. However, not all the hypotheses fit with the firm level exposure analysis.

[67] The "seminal" paper of Adler and Dumas (1984) pointed out that the exposure elasticity of a firm can be obtained from the coefficient of the exchange rate variable using the simple regression. This is introduced in equation (4.4). To control other macroeconomic conditions, equation (4.5) includes the return of a market portfolio. While equation (4.6) estimates the excess return of firm values to the change in the exchange rate. Previous studies have different preferences in choosing models from equations (4.4)-(4.6) for measure the exchange rate exposure. Many researchers believe that the three-factor model (equation (4.6)) is appropriate for measuring exposures as investors' expected returns on a firm should be higher than the return of a risk-free rate. This chapter will examine the appropriateness of these models by analysing the empirical results.

The three-factor is inappropriate for the exposure measurement at the firm level due to the very small number of observations for the risk-free rate (the 7-day Treasury bills rate).[68] In designing the research framework, the extant literature suggests that there is a relationship between firm size and the degree of exchange rate exposure (Jorion, 1990; Bodnar and Wong, 2003; Doukas et al., 2003; Dominguez and Tesar, 2006; Chue and Cook, 2008; Hutson and Odriscoll, 2010; Huffman et al., 2010). The lagged exchange rate variable also plays an important role in the exchange rate exposure analysis (Williamson, 2001; Martin and Mauer, 2003a,b). Therefore, this chapter has two more assumptions for exposure measurement at the firm level.

- **Hypothesis 3**: H0: There is a strong correlation between firm size and the exchange rate exposure; H1: there is no correlation between firm size and the exchange rate exposure.

- **Hypothesis 4**: H0: Lagged exchange rate changes have significant exposure effects on firm returns; H1: firm returns are subject to lagged exchange rate changes.

4.3.2 Dynamic Conditional Correlation Multivariate GARCH

The conventional method for estimating the CAPM is ordinary least square (OLS) regression (Fama and French, 1993; Dominguez and Tesar, 2001, 2006; Bodnar and Wong, 2003; Fraser and Pantzalis, 2004; Chue and Cook, 2008; Hutson and Odriscoll, 2010). The exposure measurement is to estimate and test the significance of beta coefficients. If the beta for exchange rate changes is equal to zero, it implies that the firm j (or industry j) suffer the same exposure as the market portfolio. This means the firm is not affected by exchange rate changes. If the zero assumption of the exposure coefficient cannot be rejected, it implies the existence of market inefficiency to some extent. The empirical strategy for exposure estimation using the cross-sectional data is to calculate the average of exposure coefficients, the percentages of exposed firms or the number of significant positive and negative exposure coefficients (Jorion, 1990; Dominguez and Tesar, 2001, 2006; Fraser and Pantzalis, 2004; Kiymaz, 2003; Hsin et al., 2007; Muller and Verschoor, 2007). The three theoretical models are implicitly assumed to have constant variances, but financial time series data

[68] There are only 8 annual observations for RF_t, which is not suitable for the exposure analysis at the firm level using the three-factor model.

usually do not hold this assumption and the homoscedasticity assumption on error terms may be invalid under the OLS regression. Therefore some studies consider the test of time-varying heteroskedasticity in the residuals $\varepsilon_{j,t}$ (Bodnar and Gentry, 1993; Muller and Verschoor, 2006; Jayasinghe and Tsui, 2008).

This chapter follows Engle (2002) to estimate the CAPM in the dynamic conditional correlation multivariate generalized autoregressive conditional heteroskedasticity (DCC MGARCH) model. It models the conditional covariance matrix of error terms in the MGARCH applying a nonlinear combination of GARCH(1,1) model with time-varying cross-equation weights (Engle, 2002, 2009; Aielli, 2013). In the existing literature, the specification techniques for the time-varying conditional covariance matrix H_t in the MGARCH models determine their trade-offs between the flexibility and the parsimony. The DCC MGARCH model is more parsimonious than the diagonal vech MGARCH (DVECH GARCH) model,[69] and more flexible than the conditional correlation MGARCH (CCC MGARCH) model, and about as flexible as the varying conditional correlation MGARCH (VCC GARCH) model. The DCC MGARCH model has been widely used in estimating exchange rate risk (Fang et al., 2007, 2009; Grier and Smallwood, 2013). Equation (4.7) gives the basic framework of the DCC MGARCH model.

$$
\begin{aligned}
y_t &= Cx_t + \epsilon_t \\
\epsilon_t &= H_t^{\frac{1}{2}} \nu_t \\
H_t &= D_t^{\frac{1}{2}} R_t D_t^{\frac{1}{2}} \\
R_t &= diag(Q_t)^{-\frac{1}{2}} Q_t diag(Q_t)^{-\frac{1}{2}} \\
Q_t &= (1 - \lambda_1 - \lambda_2) R + \lambda_1 \widetilde{\epsilon}_{t-1} \widetilde{\epsilon}'_{t-1} + \lambda_2 Q_{t-1}
\end{aligned}
\tag{4.7}
$$

Take the two-factor model as an example, y_t contains the dependent variable $R_{j,t}$, x_t is a $k \times 1$ vector of independent variables (ER_t), C is the parameter matrix and D_t is the diagonal matrix of conditional variances.[70] $H_t^{\frac{1}{2}}$ is the time-varying conditional covariance matrix and ν_t is normal $i.i.d$ innovations. R_t is a matrix of conditional quasicorrelations. $\widetilde{\epsilon}_t$ is the standardized residuals $D_t^{-\frac{1}{2}} \epsilon_t$. λ_1 and λ_2 are positive and

[69] The DVECH GARCH model is said to be less parsimonious than other MGARCH models, since the number of parameters in the DVECH GARCH model increases rapidly with the number of variables modelled.

[70] D_t is a diagonal matrix of conditional variances, by default: $\sigma^2_{i,t} = exp(\gamma_i z_i, t) + \alpha_1 \epsilon^2_{i,t} + \alpha_2 \sigma^2_{i,t}$, where γ_i is the dependent variable including a constant, α_1 is the ARCH parameter and α_2 is the GARCH parameter.

meet $0 \leq \lambda_1 + \lambda_2 < 1$. Before the application of the DCC MGARCH approach, the ARCH effect is examined by testing the residuals of the OLS regression. If it indicates the existence of ARCH effects, the lagged exchange rate variable together with the GARCH(1,1) process will be included in the specification of the conditional covariance. These parameters can be estimated by the maximum likelihood function. More details on the DCC MGARCH are discussed in Appendix A.

4.3.3 Seemingly Unrelated Regression

Due to the limited number of observations for the firm level data, the proposed DCC MGARCH model for industry level exposure analysis is inappropriate for the exposure measurement at the firm level. Considering the sample division of the firm level data, firms from different markets are divided into large firms, medium firms and small firms. In order to test Hypothesis 3, this chapter investigates whether exposure coefficients (betas) are significantly different across different size of firms. The seemingly unrelated regression (SUR) proposed by Zellner (1962) is applied in the study of Williamson (2001) to account for the cross-sectional dependence in the residuals. If the cross-sectional correlations do not exist, then the SUR is equivalent to the OLS regression. Take the two-factor model as an example:

$$R_{j,t} = \beta_{0,j} + \sum_{k=0}^{2} \beta_{k,j} ER_{t-k} + \varepsilon_{j,t} \tag{4.8}$$

Where $\beta_{k,j}$ is the exposure coefficient (beta) of the exchange rate, j denotes different types of firms (large, medium and small firms). k is the lag length. A maximum of 2 lags are initially included in the model. The optimum lag length is selected by the general-to-specific (G2S) approach. The investigation of Hypothesis 3 is testing that whether the coefficients of exchange rate changes in each model jointly estimated by the SUR are equal to each other or not. For example, the test of the degree of the firm exposure to the change in the NER in the Shanghai A-share market should be the Wald test: $\beta_{SHA_{large}} = \beta_{SHA_{medium}} = \beta_{SHA_{small}}$. If the null hypothesis cannot rejected, it means that the estimated exposure betas are equal to each other and NER changes have the same effect for the returns of large, medium and small firms. For a given SUR model, the error term is correlated with each other across stacked equations. The estimation of the SUR is a standard two-step estimation and Appendix B has the details.

4.4 Data and Preliminary Statistics

The existing literature suggests that the degree of exchange rate exposure to firm values may vary across industries. Firm size and market segment are also important factors in examining exposures. To fully investigate the exchange rate exposure of Chinese firms, both the industry and firm level data were collected for this chapter. With the continuous raising in the level and quality of the opening-up policy, Chinese firms are increasingly participating in the global market. These firms buy and sell products overseas, which means they are exposed to exchange rate changes. Therefore this chapter selects the sample of Chinese listed firms which are exporting firms from the Chinese stock market. The rates of return for these listed firms are important factors for investigating exposure effects from the foreign exchange market. The following two subsections give the general description of the data source and preliminary statistics.

4.4.1 Industry Level Data

Industry level data were obtained from the Chinese Dazhihui securities trading software.[71] The chapter has referred to the classification of Chinese industries according to the China Securities Regulatory Commission (CSRC), the Shanghai Stock Exchange (SHSE) and the Shenzhen Stock Exchange (SZSE). The industry level data are indexes which are calculated by weighting on the closing prices of those sample stocks from the SHSE and the SZSE. Each index cover almost all of the listed stocks within the same category in the Chinese stock market, except those stocks that have reported losses in their latest financial statements.[72] There are 31 industries in total according to the classification method, but this chapter excludes 3 financial industries (banks, securities and insurance) and 4 non-exporting industries (real estate, electric power, education&media and gas&water supply).[73] The final sample is constituted by 24 industries. The sample of industry level data covers the period from September 2006 to April 2014.

[71] See the website: www.gw.com.cn.

[72] The index is adjusted every half year and no more than 10% of the sample stocks will be altered for each adjustment. However, if any stock has gone bankrupt or delisted from the market, it will be deleted and substituted by the stock with higher ranking performance from the shortlist.

[73] Financial industries are excluded from the sample due to their unique asset structures and business objectives with regard to financial risks. (Bartram, 2004). Non-exporting industries mainly do their businesses inside China, hence this chapter assumes that non-exporting firms do not suffer from exchange rate changes.

The existing literature uses a variety of exchange rate variables. The frequently used indicators for observing exchange rate changes are the trade-weighted effective exchange rate (TWEER) and the bilateral exchange rate. In order to examine different exposure effects from various types of exchange rate changes, this chapter includes the nominal exchange rate (NER) of USD to RMB, the real exchange rate (RER) and the TWEER. The monthly nominal exchange rate of USD/RMB was obtained from the Dazhihui trading software. The US and China consumer price index (CPI) were collected from the Bureau of Labor Statistics of the United States and the China Statistic Database, respectively.[74] The trade-weighted effective exchange rate is collected from the Bank for International Settlements (BIS).

Since the conventional two-factor CAPM does not take returns of the market portfolio into account, this chapter would like to include market returns in the model, which measures the exposure of market portfolio to exchange rate changes (Dominguez and Tesar, 2001, 2006). As industry level data are indexes that are based on the whole listed firms from both the SHSE and the SZSE, the market portfolio variable should also be selected from both markets. The Shanghai Stock Exchange Composite Index (SHCOMP) represents the market trend of all stocks listed in the SHSE. It is a necessary and practical tool for market practitioners to judge the fluctuation of stock prices. The Shenzhen Stock Exchange Component Index (SICOMP) reflects the variation of stock prices and general trend of the Shenzhen-A share and the Shenzhen-B share, which consists of 40 typically listed firms with high returns.[75] It offers comprehensive and objective performance assessment benchmark for investors and practitioners. Both the SHCOMP and the SICOMP indexes can be obtained from the Dazhihui securities trading software.

The risk-free rate is the expected minimum return on a portfolio with the assumption of no risks. The individual asset's continuous rate of return should be in excess of the return of risk-free rate (Chow et al., 1997). Thus the CAPM framework for measuring exchange rate exposure is an augmented form which includes the returns of market portfolios and the risk-free rate (Huffman et al., 2010; Du and Hu,

[74]The real exchange rate of USD/RMB is adjusted by foreign and domestic price levels. $RER_t = NER_t \frac{P_t^*}{P_t}$, where the NER is the nominal exchange rate of USD/RMB, P_t^* and P_t are the foreign and domestic CPI.

[75]The Shenzhen Stock Exchange Component Index (SICOMP) is the most representative index for observing the volatility of stock prices in the SZSE. It includes all Chinese firms listed in the main board, small and medium-size enterprise (SME) board and growth enterprise market (GEM). this chapter uses the SICOMP as a proxy due to the unavailability of some SICOMP data.

2012). In practice, the return on the 3-month Treasury bills or the 30-day Treasury bills are preferred proxies for the risk-free rate (Hsin et al., 2007; Huffman et al., 2010). These proxies are usually assumed to suffer less risk since the non-default credibility of the US government is widely accepted by the public. However, for selecting the risk-free rate, there is a controversy between the Shanghai Interbank Offered Rate (Shibor) and the Chinese Treasury bills preferred risk-free rate. As a matter of fact, the Shibor market participants are commercial banks but the Chinese treasury market participants include commercial banks, securities, institutional and individual investors.[76] This chapter uses the 7-day Treasury bills rate as the risk-free rate given it has good mobility, low risk, stable returns and active transactions. It can also be obtained from the Chinese Dazhihui securities trading software.

Figure 4.1 gives the plots for market indexes and three types of exchange rates.[77] The SHCOMP and the SICOMP basically have the same trend as shown in Figure 4.1. Both indexes experienced a dramatic increase around 2007 but suffered great depression in the 2008 global financial crisis. The NER maintained at the horizontal level before 2005, but the RER shows an upturn trend after adjusting for inflation. After 2005, both the NER and RER graphs show the appreciation of the Chinese currency. The TWEER represents the purchasing power of a currency. The increase in the TWEER suggests the strength of the Chinese currency against those of trade partners. In general, the purchasing power of the RMB is increasing although there were some distress periods around 2005 and 2008. Figure 4.1 also plots the 7-day Treasury bills rate. Its constant returns indicates that it is appropriate to be used as the proxy for the risk-free rate, although there was a drastic fluctuation around 2007.

4.4.2 Firm Level Data

Firm level data were collected from the online stock database of the NetEase company. The financial statements of Chinese listed firms are usually announced each quarter. At the firm level, operating incomes are used as proxies for measuring firm

[76] Gao, P.L.and Xia, Y.Y.(2013). Benchmark rate selection in China. Theorists (1):14. (in Chinese).

[77] In Figure 4.1, the sample of stock market indexes (SHCOMP and SICOMP) and exchange rates series range from 1995m12 to 2014m3. The sample for the 7-day Treasury bills rate covers the period 2006m5 to 2014m3. Considering the consistency of data frequency, the final sample range is selected from 2006m9 to 2014m3 for the industry level exposure analysis.

values in response to exchange rate changes.[78] After checking the number of observations, the annual data set for this chapter covers the period 1991 to 2013.[79] Since the existing literature suggests that firm size usually has a strong correlation with the exchange rate exposure (Muller and Verschoor, 2007; Chue and Cook, 2008; Bodnar and Wong, 2003; Kiymaz, 2003), thus the total asset in each reporting period is used to differentiate the size of firms. Those firms listed after 2010 are not included in the sample because of the very small number of observations. Non-exporting firms and those firms labelled as special treatment stocks are also excluded from the sample.[80] The final sample of firm level data is constituted by 701 firms from the Shanghai A-share market, 44 firms from the Shanghai B-share market, 662 firms from the Shenzhen A-share market and 45 firms from the Shenzhen B-share market. The market level data consist of the Shanghai A-share Index (SHAI), the Shanghai B-share Index (SHBI), the Shenzhen A-share Index (SZAI), the Shenzhen B-share Index (SZBI), the SHCOMP and the SICOMP. The annual market level indexes and exchange rate series have the same data sources as industry level data.

4.4.3 Data Transformation and Preliminary Statistics

Exchange rate exposure is measured as the sensitivity of firm values to exchange rate changes. At the industry level, the sensitivity of industry returns to exchange rate changes is defined as the natural logarithmic return of each index. $R_t^j = ln\frac{R_t^j}{R_{t-1}^j}$, where j is each individual industry and t represents time. The fluctuations in exchange rates and market returns are measured on the same basis.[81] As the SHCOMP and the SICOMP represent the market portfolio in the SHSE and the SZSE, respectively, the composite market returns should be the combination of the rates of returns of the two markets. Market returns are defined as the average return of the Shanghai and Shenzhen stock markets: $RM_t = \frac{RM_t^{SHSE}+RM_t^{SZSE}}{2}$, where RM_t^{SHSE} and RM_t^{SZSE} denote the market return of the Shanghai and Shenzhen stock mar-

[78]The operating income is usually used as a proxy for cash flows (Martin and Mauer, 2003a,b).

[79]The mix of quarterly and annual data frequency in the data really matters the selection of data frequency. The quarterly data for these listed firms are not continuous and most of them are missing before 2000. In order to be in line with the frequency of market level data and to observe the complete exposure effects, annual data are applied in the firm level exposure analysis.

[80]Special treatment of stocks refer to those listed companies that have problems in their financial conditions, such as continuous losses. Once a stock has been labelled as "ST", it implies the existence of potential risks and delisting.

[81]Real exchange rate of USD/RMB is expressed in the formula of footnote 74.

kets, respectively.[82] Summary statistics of industry level data are reported in Table 4.1. There are not any dramatic changes exhibiting in the individual industry returns. Most series have a zero mean and normal distribution. The normality can be reflected from the Kurtosis values in the table.

Table 4.2 reports stationary tests for industry level series. Two kinds of unit root tests are applied. The Augmented Dickey-Fuller (ADF) test captures the complex patterns hidden in time series data (Dickey and Fuller, 1979), while it is believed that the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root test have more power and less size distortion for small samples (Im et al., 2003). The linear restrictions for both tests are the inclusion of constant terms. All series at industry level are stationary in their levels as shown in Table 4.2.

At the firm level, this chapter divides the sample into the group of large, medium and small firms according to the average of their total assets. The division of firm size is in line with the study of Chue and Cook (2008). If the average total assets are greater than ¥6 billion, the firm is considered to be a large firm. Similarly, medium firms have average total assets between ¥1 billion and ¥6 billion, and the average total assets for small firms are less than ¥1 billion.[83] The unanticipated changes in firm values are designated as log returns of operating incomes. $OPI_t^j = ln\frac{OPI_t^j}{OPI_{t-1}^j}$, where OPI_t^j is the operating income of firm j at time t. The approach of logarithmic return has also been applied to the exchange rate and market level stock indexes. The market returns for Shanghai and Shenzhen stock markets are the returns of the SHCOMP and the SICOMP, respectively. The overall market return is defined as the average return of the SHCOMP an the SICOMP. Table 4.3 reports the summary statistics of the firm level data. The stationarity of firm level data is not tested due to the small number of observations. Therefore, a caveat to bear in mind is that the times series approach might be inappropriate for exposure measurement at the firm level in this chapter.

[82] This chapter assume that both markets have the same weights, therefore the market returns of the Chinese stock market is the average return of the Shanghai and Shenzhen markets.

[83] In the study of Chue and Cook (2008), a firm is considered to be a large firm if its mean assets are larger than 1 billion dollar. In this paper, the average total assets for large firms are more than 6 billion RMB, simply because currently the foreign exchange rate of USD/RMB is 6.18.

4.5 Exchange Rate Exposure of Chinese Firms at the Industry and Firm Level

To investigate the exchange rate exposure of Chinese firms, this chapter takes into account exposure measurement from both industry level and firm level data. The industry level data are indexes which represent the market trend of the specific industry in the Chinese stock market. While the firm level data were collected from financial statements which represent unanticipated changes in operating incomes at the micro level. The investigation of the exchange rate exposure of Chinese firms at both the industry and firm level is novel and can substantiate the consistency of the results at differing levels of aggregation.

4.5.1 Measuring Exposures at the Industry Level

The exchange rate exposure at the industry level is modelled by industry based on the theoretical models of equations (4.4)-(4.6). Each model investigates different exposure effects from different types of exchange rate changes. The econometric strategy for estimating these models is the DCC GARCH approach (see equation (4.7)). Before the application of the DCC GARCH approach, ARCH effects of each model have been examined using a linear regression test. If the homoscedasticity of error terms $\varepsilon_{j,t}$ in the linear regression tests are rejected, the GARCH(1,1) process will be included in the DCC GARCH model. Otherwise, only the mean model will be estimated, which is almost equivalent to the linear CAPM estimated by OLS. Tables 4.4-4.12 report the exchange rate exposure measurement at the industry level. For the two-factor CAPM, none of the linear regression tests indicate the existence of ARCH effects. However, ARCH effects exist in some industries based on the market model estimates. The three-factor model estimates also indicate the existence of ARCH effects in the regression residuals of some industries. The detailed list of industries with ARCH effects in the linear regression of the CAPM can be found in table notes of Tables 4.7-4.12.

Tables 4.4-4.6 report the two-factor model for measuring exchange rate exposures based on equation (4.4). It measures the total exchange rate exposure of industry returns. It is clear that Chinese firms are less likely to be exposed to the change in the bilateral nominal exchange rate of USD/RMB at the industry level. This suggests that these industries are not affected by the Sino-US nominal bilateral exchange rate since the currency reform of China in 2005. The majority of exposure coefficients (betas) are statistically significant at the 5% level in the measurement of industry returns to changes in the RER and the TWEER. In the test of the exposure to RER changes, see Table 4.5, the exposure coefficient for the wine and food industry is not significant at the 5% level. The remaining exposure coefficients (for the RER) are significant at the 5% level. In testing the exposure to TWEER changes, see Table 4.6, most exposure coefficients (for the TWEER) are statistically significant at the 5% level, except AFHF, computer, electronic information, medicine, paper-making and printing, textile and garment, and other industries (miscellaneous). Besides the exposure coefficients for exchange rate changes, the coefficients for lagged exchange rate changes are also reported in Tables 4.4-4.6, but they are not statistically significant.

The exposure betas are positive for the RER but negative for the TWEER. For instance, both the exposure betas are significant at the 5% level in estimating the building construction industry to RER and TWEER changes. An increase in RER fluctuations (RMB depreciation) by 1% raises the return of the building construction industry by 2.435%. But an upturn of 1% in the TWEER reduces the return of building construction industry by 1.62%. The reason for the discrepancy is due to the different measurement of the RER and the TWEER. The RER for this chapter is the bilateral exchange rate of USD/RMB. An increase in the RER means the depreciation of the Chinese currency. It strengthens the competitiveness of exports and then further increases industry returns. The TWEER reflects the purchasing power of one currency. If the TWEER goes up, it implies the strength of the currency against those of trade partners. This benefits the country's imports since its imports become relatively cheaper, but undermines the competitiveness of its exports. Comparatively, information criteria values for each industry in Table 4.5 and Table 4.6 are higher than those reported in Table 4.4. This may indicate that industry returns are more likely to be exposed to the changes in the RER and the TWEER. However, this chapter examines the appropriateness of three different models. Further conclusions on the model selection should be given after the analysis of the market model and three-factor model estimates.

Tables 4.7-4.9 report the market model estimates for measuring exchange rate exposure based on equation (4.5). Only the exposure coefficient for the change in the NER is significant in the AFHF industry in Table 4.7. Other industries are found to be resilient to NER fluctuations. In Table 4.8, three industries are found to be exposed to RER changes, namely electrical equipment, paper-making and printing, wine and food industries. Moreover, Table 4.9 reports exposure estimates of industry returns to the change in the TWEER. Four industries are subject to TWEER changes, including AFHF, coal and petroleum, commercial chains and non-ferrous metals industries.

In addition to the exposure coefficients for exchange rates, the exposure betas for market returns are also reported in Tables 4.7-4.9 using the market model for measuring industry level exposure. The inclusion of a market portfolio in the exchange rate exposure measurement equation takes into account macroeconomic effects that affect firm returns. Not surprisingly, all the coefficients for market returns are statistically significant at the 1% level. It means that the fluctuation in the market portfolio plays an important role in determining industry returns. This is true in China, since the Chinese stock market is not as mature as advanced stock markets, such as the US stock market, macroeconomic influences are the main systematic risk for industry returns. However, with the increasing number of Chinese firms selling products overseas and the gradual relaxing of the RMB exchange rate system, the change in the exchange rate is affecting the Chinese stock market. Another striking feature is that AIC and BIC values of the market model are smaller than the two-factor model. This means that the market model for measuring industry level exposure is more likely to be accepted.

Tables 4.10-4.12 report the three-factor model for measuring industry level exposure, which estimates the exposure of excess industry returns to the changes in excess market returns and in exchange rates. In Table 4.10, three industries (AFHF, commercial chains, wine and food industries) are subject to NER changes. Table 4.11 represents the exposure measurement to the change in the RER. Five industries are found to be exposed to RER changes, namely chemicals, electrical equipment, electronic information, foreign trade, wine and food industries. Table 4.12 gives the exposure measurement of industry returns to the change in the TWEER. There are seven industries exposing to TWEER changes. Similarly, all parameters for market returns are statistically significant at the 1% level. In terms of information criteria, there are no much difference in the magnitude of AIC and BIC values, but it is difficult to ascertain the best model. However, amongst the three models for measuring exchange rate exposure, information criteria seem to suggest that both the market model and the three-factor model can be used to estimate the exchange rate exposure of industry returns. Both the estimated exposure coefficients and information criteria values indicate that the two-factor model for estimating exchange rate exposure might be inappropriate.

The results in Tables 4.4-4.6 show that some industries are subject to lagged exchange rate changes, this is in accordance with the established evidence that one-period lagged exchange rate changes may affect firm returns (He and Ng, 1998; Fraser and Pantzalis, 2004). However, the majority of them are not statistically significant. The inclusion of the lagged exchange rate variable might affect the model estimates. Therefore, we reestimate those equations but exclude those with non-significant lagged exchange rate variables from the DCC MGARCH model. A refined version of exchange rate exposure measurement at the industry level is reported in Table 4.13. This table gives a clear representation of exposure betas estimated from three different models, in which the exposure to the changes in the NER, RER and TWEER are examined separately. Apparently, the exclusion of non-significant lagged exchange rate variables can improve model estimates.

Table 4.14 reports summary statistics of exposure betas at the industry level. For the two-factor model estimates, twenty two industries suffer negative exposure effects from the TWEER changes, which account for 91.67% of the total number of sample industries. The average exposure beta is -2.308, which indicates that the average industry return will decrease by 2.308 units when changes in the TWEER increase by 1%.[84] Twenty three industries are exposed to positive exposures resulting from RER changes, which account for 95.83% of the total number of sample industries. Both types of exposure betas are much higher than the exposure coefficients in the papers of Jorion (1990) and Muller and Verschoor (2006). The two-factor model examines the total exchange rate exposure of industry returns. If changes in industry returns and exchange rates are essentially unanticipated, the two-factor model is appropriate (Jorion, 1990). However, the real situation in the Chinese stock market is a little different from other advanced markets because of the implementation of a managed floating exchange rate policy. Any serious unexpected shocks happening in the foreign exchange market are restricted and limited within a narrow floating range. Added to that, information criteria values in Tables 4.4-4.12 reveal that the two-factor model for exchange rate exposure measurement might be inappropriate.

[84] In this chapter, the monthly industry returns are expressed as log returns.

The summary of exposure coefficients clearly show that the change in the NER does not have a significant impact on industry returns based on the two-factor model and market model estimates. It further suggests that firm returns are less likely to be exposed to the change in the nominal exchange rate (Williamson, 2001). The percentages of significant positive and negative exposure coefficients do not exhibit too much discrepancies in the market model estimates. The average exposure coefficients are 0.019 and -0.195 in response to RER and TWEER changes, respectively, which are close to the findings from Jorion (1990) and Muller and Verschoor (2006). Compared with the two-factor model estimates, the market model estimates are convincing and more likely to be accepted. Apparently, the market model improves the model efficiency and accurately estimates exposures compared with the two-factor model. This is demonstrated by the information criterion, and also could be due to the incorporation of a market portfolio variable that control for macroeconomic effects.

For the three-factor model estimates, the major difference is the percentage of significant negative exposure betas compared with the market model. There are eight industries (account for 33.33%) significantly affected by changes in the TWEER, which is relatively higher than those negative exposure coefficients (8.33%). The average exposure coefficient is -0.346. It implies that the average industry return declines by 0.346% when the TWEER fluctuation increases by 1%.[85]

In general, the exchange rate exposure measurement at the industry level has several important implications for future studies. First, building upon the conventional CAPM framework, the two-factor model is inappropriate for measuring the total exchange rate exposure of industry returns, particularly in the context of the implementation of a managed floating exchange rate system in China. This is consistent with the evidence in the existing literature on investigating exchange rate exposure (Bodnar and Gentry, 1993; Dominguez and Tesar, 2001; Muller and Verschoor, 2006; Huffman et al., 2010; Du and Hu, 2012). Second, the degrees of exposure to the changes in the NER, RER and TWEER are quite different. With the deepening of the opening door policy and the gradual relaxing of the managed floating exchange rate policy, Chinese industries are exposed to RER and TWEER changes, rather than the change in the NER. Third, the majority of Chinese indus-

[85] The increase in the TWEER reduces the cost of one country's imports but at the same time undermines the competitiveness of its exports.

tries are significantly exposed to negative shocks from the change in the TWEER, but to positive shocks from RER changes. This is due to their different compiling methods. As an increase in the RER means the depreciation of the RMB , while an increase in the TWEER indicates the strengthen of the Chinese currency. Thus the effects from changes in the RER and the TWEER are opposite in sign. Fourth, the 7-day Treasury bills rate is used as a proxy of risk-free rate in this chapter, which may not perfectly fit with the CAPM framework for measuring exchange rate exposure of excess industry returns.[86] Finally, the empirical evidence reveals that both the market model and the three-factor model are appropriate for measuring exchange rate exposure of Chinese firms at the industry level, which also suggests that the exposure to the change in the TWEER is more powerful in interpreting the variation of industry returns in China, especially after the RMB exchange rate system reform in 2005.

4.5.2 Measuring Exposures at the Firm Level

The exchange rate exposure of Chinese firms at the firm level is only estimated from the two-factor model and the market model. The three-factor model is not estimated due to the small number of observations. As demonstrated in the data description section, the firm level data from different markets are divided into large, medium and small firms according to their average total assets in the sample period. Table 4.15 reports the exchange rate exposure of Chinese firms at the firm level. For each market, an additional F-test (Wald test) is conducted to examine whether these exposure coefficients vary across equations. Three types of firms are stacked into a system and jointly estimated by the SUR. If there is correlation in the cross-equation residuals, then the SUR estimation is a more efficient estimator. If there are no cross-equation correlations presence, the SUR is equivalent to the OLS approach (Zellner, 1962; Williamson, 2001).

In the Shanghai stock market, RMB ordinary share markets and foreign capital shares markets are investigated separately. Exposure coefficients for small firms are statistically significant as demonstrated both in the two-factor model and the market model estimates. It suggests that small firms listed in the Shanghai A-share market are more likely to be exposed to the change in the NER. However,

[86] Although the 7-day Treasury bills rate has several good properties, such as good mobility and active trade, the Chinese bond market is still far less sophisticated than the US bond market.

the $F\text{-}test_{SHA}$ accepts the null hypothesis that the exposure beta is equal to each other, which means that there is no correlation between firm size and exchange rate exposure in the Shanghai A-share market. Although Wald tests suggest that exposure coefficients may vary across equations in the test of the exposure to the change in the RER, the exposure coefficients are not statistically significant. The estimates from Shanghai B-shares demonstrate that large and medium firms suffer more exposure effects from the changes in the NER and the the TWEER, but small firms are less likely to be exposed to currency exposures. The Wald test is rejected (indicated by the diamond symbol in Table 4.15) which means that the estimates are the same as an OLS estimates. It is apparent that the exposure coefficients for large firms (SHB_{Large}) and medium firms (SHB_{Medium}) are not very different in magnitude, particularly in response to the change in the TWEER.

In the Shenzhen stock market, the estimates from Shenzhen A-share firms are quite different from Shanghai A-share firms. The cross-equation correlation in the errors exists in the two-factor model in testing the exposure to the change in the TWEER. The exposure coefficients for large firms (SZA_{Large}) are significant in levels but only the coefficients for lagged TWEER variables are significant for medium (SZA_{Medium}) and small firms (SZA_{Small}). For the market model estimates, there exists cross-equation correlation in the residuals and the exposure betas vary across equations as revealed by the F-test ($F\text{-}test_{SZA}$). These results also suggest that large and small firms have a strong correlation with the TWEER fluctuation in the Shenzhen A-share market, while medium firms are more likely to be exposed to the change in the RER. For the exposure measurement in the Shenzhen B-share market, the majority of model estimates do not exhibit cross-equation correlation in the residuals. The lagged NER and TWEER changes have significant exposure effects on the medium-size firms. Nevertheless, no significant results can be found in exploring exposures to RER changes.

The exchange rate exposure of firm returns from the aggregate Shanghai and Shenzhen stock markets are also examined. For the estimates from the SHSE, small firms are subject to changes in the NER, but the null hypothesis of equal exposure betas across equations cannot be rejected (see $F\text{-}test_{SHSE}$), which implies that the correlation between firm size and exchange rate exposure does not exist in the SHSE. The null of the equivalent exposure betas across equations has been rejected (see $F\text{-}test_{SZSE}$). For the estimates from the SZSE, large firms are more likely to suffer from TWEER fluctuations, while medium and small firms receive relatively small effects from TWEER changes. The exposure beta for medium firms is statistically significant at the 5% level in testing the exposure to RER changes, but the Wald test ($F\text{-}test_{SZSE}$) of equal exposure coefficients across equations cannot be rejected. This means that no strong correlation exists between firm size and exposure effects.

Table 4.15 also investigates the exchange rate exposure of all sample firms, including both RMB ordinary shares and foreign capital shares. In the test of the exposure to the changes in the NER and RER, none of the exposure betas are statistically significant. While investigating the exposure to TWEER changes, firm returns are significantly exposed to lagged exchange rate changes. This is consistent with previous exchange rate exposure studies (Williamson, 2001; Doukas et al., 2003; Fraser and Pantzalis, 2004). Both the Wald tests ($F\text{-}test_{SHSZ}$) for the level and lagged exchange rate changes indicate that exposure betas vary across equations. It is evident that large firms suffer more exposure effects than small firms as demonstrated in the whole sample test. In addition, the exposure betas from the two-factor model and the market model are not very different. The Wald test indicates that firm returns are not exposed to the change in market returns (not reported). This is quite different from the results of the capital market approach for measuring exchange rate exposure at the industry level (see Tables 4.7-4.12), which strongly shows that industry returns are significantly exposed to changes in the market portfolio. A possible explanation for this could be the disparity of two approaches in measuring exchange rate exposure. The capital market approach measures the operating exposure of firm returns, while the cash flow approach measures the transaction and translation exposure of firm values.

4.6 Discussion

This chapter has investigated the exchange rate exposure of Chinese firms at the industry and firm level. In general, this chapter differs from previous studies mainly in the following aspects. First, the exchange rate exposure of Chinese firms are examined at both the industry and firm level. The industry level analysis gives an in-depth investigation of the exposure to a specific industry at the macro level, whereas the firm level analysis examines the exposure of Chinese firms to exchange rate changes at the micro level. Second, two types of approaches for exchange rate exposure measurement are applied. Under the conventional CAPM framework, the capital market approach is used to measure exposure at the industry level, while the cash flow approach is introduced to measure the firm level exposure. Third, the changes in the NER, RER and TWEER are examined separately in order to observe which kind of exchange rate changes has the largest influence on Chinese firms. The exposure to the change in the TWEER is not investigated at the firm level due to the small number of observations. Fourth, the Chinese stock market is constituted by RMB ordinary shares and foreign capital shares. To examine different exposure effects across different stock markets, the exchange rate exposure of these listed firms from different markets are estimated separately. The exposure to all sample Chinese firms are also jointly estimated.

At the industry level (see Tables 4.4-4.14), several implications can be derived from the analysis. First, the market model and the three-factor model are more competent and effective in measuring exchange rate exposure of Chinese firms at the industry level than the two-factor model. This accords with the existing literature where a number of studies take the market return into account since the two-factor model is only appropriate when the changes in firm values and exchange rate are completely unexpected in nature (Jorion, 1990; Kiymaz, 2003). Lagged exposure effects imply that exchange rate changes in China are not totally unexpected, but intervened by the authorities to some extent. Second, industry returns are more likely to be exposed to the changes in the RER and TWEER. The average exposure betas of industry returns to RER changes are 0.019 and 0.093 from the market model and the three-factor model estimates, respectively. Both of them are lower than the exposure to the TWEER change in magnitude. With the rise of China, Chinese firms are actively operating in the global market. The bilateral exchange rate of USD/RMB does not play a decisive role in determining the exchange rate exposure of industry returns. The results seem to suggest that the TWEER is more suitable for investigating exchange rate exposure at the industry level. As shown in Table 4.14, the three-factor model estimates represent that more than 37% of Chinese industries are significantly exposed to changes in the TWEER. The average exposure coefficient for the TWEER change is negative (-0.195 for the market model and -0.346 for the three-factor model). This means that a 1% increase in the TWEER reduces industry returns by 0.346% (based on the three-factor model estimates). Third, manufacturing industries are more likely to suffer from exchange rate changes. In testing the exposure to TWEER changes in the three-factor model, the exposure betas for the coal and petroleum, electrical equipment, non-ferrous metals and vehicles industries are statistically significant at the 5% level. Manufacturing industries are the pillar industries in China. The exports from manufacturing industries account for a large proportion of China's exports. Hence manufacturing industries should set up special commissions to manage currency risks. With the deepening of the open door policy, commercial chains and construction materials industries are also significantly exposed to the TWEER change due to the increasing interactions between Chinese service industries and the world. Therefore, to manage the currency exposure, the hedging strategy should focus on the change in the TWEER, not the nominal exchange rate of USD/RMB. Fourth, if heteroskedasticity exists in the residuals of the linear regression test, the DCC MGARCH is more efficient in estimating exchange rate exposure. Fifth, lagged exchange rate changes improve the convergence of the DCC MGARCH model and help capture dynamic exposure effects. This indicates that lagged exchange rate changes have significant exposure effects on industry returns. This is particularly significant in China, since the temporary shock might be restricted by the managed floating exchange rate policy, but the lagged exposure effect still exists. This is in consistent with previous findings about the inclusion of a lagged exchange rate variable (Williamson, 2001; Doukas et al., 2003).

For the exposure measurement at the firm level (see Table 4.15), the cash flow approach is applied to measure the exchange rate exposure of Chinese firms. Previous studies estimate the exchange rate exposure by firm using the linear regression model, then calculate the average exposure coefficient or the percentage of significant exposure coefficient. While this chapter divides the sample firms into groups (large, medium and small firms) according to their average total assets. The exchange rate exposure measurement at the firm level is to estimate the exposure of each group of firms. The results from the SUR model indicate that exposure effects vary across markets. In the SHSE, no evidence supports the existence of the correlation between firm size and the exchange rate exposure. The firms listed in the Shanghai B-share market also do not have correlated cross-equation residuals in the SUR estimates. While in the SZSE, there is a strong correlation between firm size and the exchange rate exposure in testing the TWEER change in the Shenzhen A-share market, but size effects and cross-equation contemporaneous correlation across equations do not exist in the Shenzhen B-share market. If there is no division between A-shares and B-shares, the results are almost consistent with the estimates from each individual market. The discrepancy might be due to the trading currencies of RMB ordinary shares and foreign capital shares. The Shenzhen A-shares are traded in local currency (RMB), which will be affected by changes in the foreign exchange rate. While Shenzhen B-shares are foreign capital shares which are traded in HKD. Theoretically, the change in the exchange rate might affect firm returns of Shenzhen B-shares, since the HKD is closely linked to the USD. Nevertheless, the managed floating exchange rate system might have helped to protect Chinese firms from external shocks to some extent. Although the Shanghai market does not show potential size effects, the whole sample estimates confirm the existence of a strong correlation between firm size and the exchange rate exposure in investigating the exposure to TWEER changes (indicated by $F\text{-}test_{SHSZ}$). The unanticipated changes in operating incomes suffer exposure effects from lagged TWEER changes. This accords with previous studies in the preference of incorporating a lagged exchange rate variable in the model (Williamson, 2001; Doukas et al., 2003). This is also consistent with the evidence from the industry level exposure analysis. It is clear that large firms are more frequently exposed to exchange rate changes than small firms. Small firms are less likely to be exposed to exchange rate exposure, since they are less involved in global operations. It might also be the ongoing managed floating RMB exchange rate system that generates lagged exposure effects. Whenever there is an unanticipated changes happening in the exchange rate, it exhibits little effects on firm returns, since the currency daily trading band is restricted within a limited range.[87] Any severe shocks from exchange rate changes will be limited by such a policy, but if the shock continues, the lagged exposure effect on Chinese firms appears to be significant.

It seems that the results from this chapter are in contradiction with the findings from Chapter 3, since Chapter 3 implies that exchange rate changes cannot Granger-cause stock returns in the long run, but empirical estimates in this chapter shows that exchange rate changes have significant influences on firm returns. This is true in the case of China. Currency exposure exists at different levels. The Chinese authorities impose restrictions on the currency's daily trading band, which protects the Chinese financial market against external shocks. While at the industry and firm

[87]Since March 2014, the daily floating range was expanded to 2%.

levels, different industries/enterprises have different degrees of participating in global operations. Large firms comparatively have more overseas operations than small firms, and therefore they are more likely to be subject to exchange rate exposure. The application of different datasets and methods in the two chapters also causes dissimilarities in effects of exchange rate changes.

4.7 Conclusions

This chapter has examined the exchange rate exposure of Chinese firms at both the industry and firm levels. At the industry level, the exchange rate exposure of industry returns is investigated individually building upon the capital market approach. The DCC MGARCH estimates indicate that the market model and the three-factor model are appropriate for measuring exchange rate exposure of Chinese firms at the industry level, which also implies that industry returns are more likely to be exposed to the changes in the RER and the TWEER, but the average exposure beta of the RER change is lower than that of the TWEER change in magnitude. Among these industries, manufacturing industries receive more shocks from exchange rate changes, such as the industry of coal and petroleum, electrical equipment and vehicles. The evidence also seems to suggest that the DCC MGARCH model has more power in estimating the CAPM when ARCH effects exist in the linear regression test. At the firm level, 1452 Chinese firms, which account for 55.71% of the total firms listed in the A-share markets and B-share markets, are divided into large, medium and small firms in order to test the correlation between firm size and exposure effects. The cash flow approach measures the exchange rate exposure of unanticipated changes in operating incomes, which is a proxy of cash flows. Concerning the econometric strategy, the SUR model is used to estimate the exposure across equations, in which the linkage between firm size and exposure effects can be tested when the cross-equation contemporaneous correlation exists. Although the exposure effect varies across different stock markets, the whole sample estimates reveal the existence of size effects in testing the exposure to TWEER changes. In magnitude, large firms are more frequently suffered from exchange rate changes than small firms, since large firms have more overseas operations, while small firms are mainly aiming at the domestic market. Moreover, both the industry level and firm level results show that lagged exchange rate changes have a significant impact on firm returns. This might be due to the implementation of the managed floating exchange rate system in China. However, the Chinese authorities are faced with continuous pressures from trade partners, the RMB exchange rate might have to be adjusted to be more flexible and tradable in foreign exchange markets in the near future. In order to offset and effectively manage the exchange rate exposure, this chapter finally suggests that Chinese firms should set up special commissions to hedge currency risks of their future cash flows, particularly for those non-financial firms. The hedging strategy should not only focus on the change in the USD, but a basket of currencies, since the trade-weighted effective exchange rate has the largest influence on Chinese firms.

Appendix A: Dynamic Conditional Correlation Multivariate GARCH

Recap the framework of the dynamic conditional correlation multivariate GARCH (DCC MGARCH) (Engle, 2002, 2009; Aielli, 2013):

$$
\begin{aligned}
y_t &= Cx_t + \epsilon_t \\
\epsilon_t &= H_t^{\frac{1}{2}} \nu_t \\
H_t &= D_t^{\frac{1}{2}} R_t D_t^{\frac{1}{2}} \\
R_t &= diag(Q_t)^{-\frac{1}{2}} Q_t diag(Q_t)^{-\frac{1}{2}} \\
Q_t &= (1 - \lambda_1 - \lambda_2) R + \lambda_1 \widetilde{\epsilon}_{t-1} \widetilde{\epsilon}'_{t-1} + \lambda_2 Q_{t-1}
\end{aligned}
$$

Where y_t is a $m \times 1$ vector of dependent variable $R_{j,t}$, x_t includes $k \times 1$ vector of independent variables ($RM_{j,t}$ and ER_t for this chapter) in which lagged R_t may be included. C is a $m \times k$ matrix of parameters.[88] In above DCC MGARCH model, $H_t^{\frac{1}{2}}$ is the time-varying conditional covariance matrix and ν_t is normal $i.i.d$ innovations. D_t contains a diagonal matrix of conditional variances. The diagonal conditional covariance matrix is expressed as follows:

$$
D_t = \begin{pmatrix} \sigma_{1,t}^2 & 0 & \dots & 0 \\ 0 & \sigma_{2,t}^2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \sigma_{m,t}^2 \end{pmatrix}
$$

Where each $\sigma_{i,t}^2$ develops in an univariate GARCH model expression:

$$
\sigma_{i,t}^2 = s_i + \Sigma_{j=1}^{p_i} \alpha_j \epsilon_{i,t-j}^2 + \Sigma_{j=1}^{q_i} \beta_j \sigma_{i,t-j}^2
$$

otherwise, the default form for $\sigma_{i,t}^2$

$$
\sigma_{i,t}^2 = exp(\gamma_i z_{i,t}) + \Sigma_{j=1}^{p_i} \alpha_j \epsilon_{i,t-j}^2 + \Sigma_{j=1}^{q_i} \beta_j \sigma_{i,t-j}^2
$$

[88] MGARCH models have a different specification for the time-varying conditional covariance matrix of the disturbances, which can be very parsimonious and flexible. It is denoted by H_t. In the DCC MGARCH framework, $H_{ij,t} = \rho_{ij,t}\sqrt{h_{ii,t}h_{jj,t}}$, in which the diagonal elements are modelled as univariate GARCH models while the off diagonal elements are modelled as nonlinear expressions of the diagonal elements.

α_j's are ARCH parameter and β_j's are GARCH parameters in the conditional variance. R_t is the conditional quasi-correlation matrix:

$$R_t = \begin{pmatrix} 1 & \rho_{12,t} & \dots & \rho_{1m,t} \\ \rho_{12,t} & 1 & \dots & \rho_{2m,t} \\ \vdots & \vdots \ddots & \vdots & \\ \rho_{1m,t}\rho_{2m,t} & \dots & 1 & \end{pmatrix}$$

For other parameters in the DCC MGARCH model, $\widetilde{\epsilon_t}$ is the standardized residuals of the $m \times 1$ vector $D_t^{-\frac{1}{2}}\epsilon_t$, λ_1 and λ_2 are the parameters controlling the dynamic conditional quasi-correlations. λ_1 and λ_2 are positive parameters, subject to: $0 \leq \lambda_1 + \lambda_2 \leq 1$.

The DCC MGARCH model parameters can be estimated by the maximum likelihood function. If the observation t is assumed to have a multivariate normal distribution, the log-likelihood function is based on the following form:

$$l_t = -0.5mlog(2\pi) - 0.5log\{det(R_t)\} - log\{det(D_t^{\frac{1}{2}})\} - 0.5\widetilde{\epsilon_t}R_t^{-1}\widetilde{\epsilon_t}'$$

Where $\widetilde{\epsilon_t} = D_t^{-\frac{1}{2}}\epsilon_t$ is a vector of residuals and $\epsilon_t = y_t - Cx_t$. The log-likelihood function is constructed by $\sum_{t=1}^{T} l_t$. Alternatively, the log-likelihood function can be established based on the assumption of a multivariate t distribution on ν_t, If ν_t follows a multivariate t distribution, then the log-likelihood function for each observation t:

$$\begin{aligned} l_t =& log\Gamma(\frac{df+m}{2}) - log\Gamma(\frac{df}{2}) - \frac{m}{2}log\{(df-2)\pi\} - 0.5log\{det(R_t\} \\ & - log\{det(D_t^{\frac{1}{2}})\} - \frac{df+m}{2}log(1 + \frac{\widetilde{\epsilon_t}R_t^{-1}\widetilde{\epsilon_t}'}{df-2}) \end{aligned}$$

The OLS regression approach is applied to obtain the starting values for the mean equation parameters and initial residuals $\hat{\epsilon_t}$. Gourieroux and Monfort (1997) propose a method to calculate initial values for the variance equations parameters. The initial parameters λ_1 and λ_2 are generated from the grid search of the log likelihood. All the initial optimization steps are conducted in the unconstrained space. Through those constraints on λ_1 and λ_2, the log likelihood can be maximized in the constrained space.

Appendix B: Estimating Seemingly Unrelated Regression Model

The seemingly unrelated regression (SUR) model is a linear equations system, in which the errors are correlated across equations (Zellner, 1962; Fiebig, 2001), but are uncorrelated across firms. Suppose there are m-linear regression equations and N firms. The j-th equation for firm i is expressed as:

$$y_{ij} = x_{ij}^{'}\beta_j + u_{ij}$$

Where U_{ij} is the error term. The m equations are stacked into the SUR model:

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_m \end{bmatrix} = \begin{bmatrix} X_1 & \dots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \dots & X_m \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_m \end{bmatrix} + \begin{bmatrix} \mu_1 \\ \mu_2 \\ \vdots \\ \mu_m \end{bmatrix}$$

The error terms μ_j are assumed to have zero mean and to be independent across equations. The errors are correlated across equation for any given firm and have the following properties:

- Zero mean: $E(\mu_j|X) = 0$
- Variance for the j-th equation: $E(\mu_j\mu_j^{'}|X) = \sigma_{jj}I_N$
- Cross-equations covariance: $E(\mu_i\mu_j|X) = \sigma_{ij}I_N$ for $i \neq j$
- Overall variance-covariance matrix: $\Omega = E(\mu\mu^{'}) = \sum \otimes I_N$

Although the OLS estimator can yield a consistent β for each equation, the optimum approach for estimating the SUR is the GLS estimator:

$$\hat{\beta_{GLS}} = \{X^{'}(\Sigma^{-1} \otimes I_N X)^{-1}\}\{X^{'}(\Sigma^{-1} \otimes I_N y)\}$$
$$and \quad Var\hat{\beta} = \{X^{'}(\Sigma^{-1} \otimes I_N)X\}^{-1}.$$

The SUR model is estimated in two steps:

1. Estimate each equation by OLS and get the residuals and variances from m

equations via $\hat{\mu_j} = y_j - X_j\hat{\beta_j}$ and $\hat{\sigma_{ij'}} = \frac{\hat{\mu_i}'\hat{\mu_{j'}}}{N}$. This can be used to estimate Σ.

2. Substitute $\hat{\Sigma}$ for Σ of the GLS estimator $\hat{\beta_{GLS}}$.

The SUR model stacks those equations in a linear system. It is more efficient when the cross-equation correlated residuals exist. If there is no correlated error terms across equations, then the SUR estimator is equivalent to the OLS estimator. In the SUR model, the parameters vary from equation to equation, but the regressor may not vary since it is dependent on the model design. If it is necessary, we can impose cross-equation restrictions to estimate the SUR model, such as whether the coefficients are significantly different from each other.

Table 4.1: Summary statistics of industry level data

	Mean	Median	Maximum	Minimum	StdDev	Skewness	Kurtosis
AFHF	0.0047	0.0046	0.1139	-0.1346	0.0478	-0.3402	3.2701
Building construction	0.0027	0.0072	0.1266	-0.1088	0.0453	-0.2034	3.2853
Chemicals	0.0034	0.0080	0.1181	-0.1261	0.0485	-0.3270	3.2695
Coal and petroleum	0.0025	0.0028	0.1503	-0.1865	0.0537	-0.2892	4.7404
Commercial chains	0.0031	0.0011	0.1193	-0.1382	0.0446	-0.1238	3.6439
Communication	0.0030	0.0100	0.0907	-0.1394	0.0446	-0.8056	4.0210
Computer	0.0030	0.0100	0.0907	-0.1394	0.0446	-0.8056	4.0210
Construction materials	0.0056	0.0077	0.1592	-0.1465	0.0566	-0.1236	3.5388
Electrical equipment	0.0069	0.0096	0.1271	-0.1163	0.0458	-0.2341	3.4985
Electronic information	0.0041	0.0076	0.1229	-0.1603	0.0523	-0.5014	3.3819
Foreign trade	0.0054	0.0082	0.2195	-0.1924	0.0621	-0.1799	4.5446
Instruments and meters	0.0045	0.0073	0.1472	-0.1079	0.0459	-0.0577	3.6712
Machinery	0.0039	0.0094	0.1141	-0.1582	0.0516	-0.6167	3.6706
Medicine	0.0076	0.0144	0.1329	-0.1058	0.0434	-0.3440	3.5299
Non-ferrous metals	0.0019	0.0033	0.1336	-0.1786	0.0638	-0.3896	3.1613
Paper-making and printing	0.0030	0.0070	0.1189	-0.1657	0.0522	-0.5961	4.0354
Steel	0.0004	0.0032	0.1339	-0.1604	0.0560	-0.4472	3.7816
Textile and garment	0.0041	0.0029	0.1697	-0.1497	0.0520	-0.1783	4.0851
Tourism and hotel	0.0041	0.0042	0.1172	-0.1486	0.0467	-0.4565	3.7347
Transportation facilities	0.0016	0.0016	0.1335	-0.1384	0.0448	-0.2325	3.9843
Transport & logistics	0.0019	0.0027	0.1263	-0.1586	0.0496	-0.3439	3.8291
Vehicles	0.0050	0.0084	0.1117	-0.1502	0.0520	-0.5824	3.5648
Wine and food	0.0054	0.0062	0.0990	-0.1258	0.0406	-0.4526	3.6523
Other industries	0.0052	0.0119	0.1022	-0.1422	0.0521	-0.6119	3.2902
Market return	0.0026	0.0042	0.0959	-0.1190	0.0426	-0.5672	3.3553
Risk-free rate	-0.0022	-0.0165	2.5459	-2.5198	0.5693	0.0552	9.7832
NER	-0.0012	-0.0009	0.0061	-0.0074	0.0023	0.1808	4.8404
RER	-0.0004	-0.0009	0.0153	-0.0238	0.0055	-0.1507	6.2601
TWEER	0.0010	0.0009	0.0189	-0.0118	0.0054	0.3034	3.5904

Notes:
1. The sample without missing values in each individual variable ranges from September 2006 to April 2014.
2. AFHF represents the industry of agriculture, forest, husbandry and fishing.
3. NER and RER represent the nominal and real exchange rate of USD/RMB, respectively.
3. TWEER is the trade-weighted effective exchange rate.

Table 4.2: Stationary test of industry level series

	ADF	KPSS		ADF	KPSS
AFHF	-9.455***	0.278	Paper-making and printing	-9.512***	0.123
Building construction	-10.249***	0.233	Steel	-9.532***	0.307
Chemicals	-9.368***	0.170	Textile and garment	-9.536***	0.189
Coal and petroleum	-9.130***	0.180	Tourism and hotel	-8.621***	0.116
Commercial chains	-8.906***	0.187	Traffic equipment	-9.141***	0.128
Communication	-10.664***	0.168	Transport & logistics	-9.153***	0.206
Computer	-10.196***	0.137	Vehicles	-8.937***	0.120
Construction materials	-9.222***	0.213	Wine and food	-9.230***	0.243
Electrical equipment	-8.387***	0.117	Other industries	-10.202***	0.124
Electronic information	-9.941***	0.071	Market return	-9.206***	0.179
Foreign trade	-9.484***	0.197	Risk-free rate	-10.318***	0.206
Instruments and meters	-10.133***	0.235	NER	-4.219***	0.442
Machinery	-4.677***	0.182	RER	-11.282***	0.350
Medicine	-9.702***	0.151	TWEER	-6.127***	0.063
Non-ferrous metals	-8.942***	0.180			

Notes:
1. *** denotes the rejection of hypothesis at the 1% level.
2. Both the ADF and KPSS tests were carried out with the restriction of a constant only.
3. The critical values for the ADF test with a constant restriction are -3.459, -2.875 and -2.573 at the 1%, 5% and 10% levels, respectively.
4. The critical values for the KPSS test with a constant restriction are 0.739, 0.463 and 0.347 at the 1%, 5% and 10% levels, respectively.

Table 4.3: Summary statistics of firm level data

	Mean	Median	Maximum	Minimum	StdDev	Skewness	Kurtosis
SHA_{Large}	0.2423	0.2264	0.8910	0.0764	0.1568	3.1375	14.0851
SHA_{Medium}	0.1980	0.1831	0.5739	0.0131	0.1199	1.6211	6.1430
SHA_{Small}	0.1384	0.1138	0.3696	-0.0435	0.0886	0.4983	3.8642
SHB_{Large}	0.2190	0.2057	0.4251	-0.0121	0.1471	-0.0380	1.5381
SHB_{Medium}	0.1599	0.1255	0.6597	-0.1073	0.1819	1.0870	3.7942
SHB_{Small}	0.0143	0.0444	0.3358	-0.9538	0.2788	-1.9719	7.6567
SZA_{Large}	0.2997	0.2095	2.2025	-0.1073	0.4394	3.6937	16.7755
SZA_{Medium}	0.1719	0.1542	0.3708	-0.0484	0.0974	-0.1031	2.8595
SZA_{Small}	0.1487	0.1180	0.4585	-0.0060	0.1069	1.2006	4.4560
SZB_{Large}	0.1850	0.1517	0.5455	0.0192	0.1337	1.0560	3.7285
SZB_{Medium}	0.1387	0.1349	0.6470	-0.5800	0.2087	-1.1315	8.5054
SZB_{Small}	0.0517	0.0162	0.6823	-0.2254	0.2047	1.2377	4.9653
$SHSE_{Large}$	0.2426	0.2309	0.8389	0.0715	0.1475	2.8783	12.9083
$SHSE_{Medium}$	0.1956	0.1737	0.5840	0.0108	0.1225	1.5712	6.0279
$SHSE_{Small}$	0.1299	0.1151	0.2729	-0.0676	0.0834	-0.1542	3.1684
$SZSE_{Large}$	0.2631	0.2031	1.5050	-0.1073	0.3024	3.0828	13.6852
$SZSE_{Medium}$	0.1667	0.1510	0.4239	-0.1934	0.1202	-0.7012	5.2215
$SZSE_{Small}$	0.1364	0.1260	0.4099	-0.0280	0.1047	0.7378	3.5772
$SHSZ_{Large}$	0.2486	0.2351	0.7084	0.0662	0.1402	1.6287	6.3960
$SHSZ_{Medium}$	0.1850	0.1799	0.5146	0.0315	0.1092	1.3072	5.1990
$SHSZ_{Small}$	0.1426	0.1405	0.4147	0.0012	0.0838	1.3548	6.0751
SHAI	0.1241	0.0307	1.0249	-1.0606	0.4696	-0.0621	3.3073
SHBI	0.0639	0.0349	1.0340	-1.1936	0.5692	-0.1150	2.4929
SZAI	0.0622	-0.0656	1.2050	-0.9937	0.5314	0.4717	2.9672
SZBI	0.0600	0.1303	0.9208	-0.9762	0.5293	-0.0502	2.0746
SHCOMP	0.1221	0.0312	0.9805	-1.0611	0.4660	-0.0997	3.2931
SICOMP	0.0969	-0.0530	1.1809	-1.0040	0.5462	0.3474	2.6035
NER	0.0062	-0.0002	0.3716	-0.0677	0.0847	3.6585	16.5678
RER	0.0306	0.0288	0.3193	-0.0769	0.0801	1.9376	8.4605
TWEER	0.0066	0.0267	0.1079	-0.2438	0.0793	-1.4773	5.5190

Notes:

1. The sample for the firm level data covers the period 1991 to 2013, 23 observations in total. But there are only 22 observations for the variable of SZB_{Large}, SHSZ and SICOMP, and 21 observations for the indexes of BGZS, SZAG and SZBG.

2. Those variables with subscripts represent mean returns of firms' operating incomes according to the division of firm size. The sample of Chinese firms is divided into large, medium and small firms in this chapter. If the average of the firm's total assets during the sample period is greater than ¥60 billion, it is considered to be a large firm. If average total assets are between ¥10 billion and ¥60 billion, then they are regarded as medium firms. Those firms with less than ¥10 billion average total assets are small firms. The notations of capital letters indicate different markets. SHA: Shanghai A-share. SHB: Shanghai B-share. SZA: Shenzhen A-share. SZB: Shenzhen B-share. SHSE: Shanghai Stock Exchange (including those samples from Shanghai stock market). SZSE: Shenzhen Stock Exchange (including those samples from Shenzhen stock market). SHSZ: all sample firms from Shanghai and Shenzhen stock market.

3. The variables without subscripts are stock indexes and exchange rates. SHAI: Shanghai A-share Index. SHBI: Shanghai B-share Index. SZAI: Shenzhen A-share Index. SZBI: Shenzhen B-share Index. SHCOMP: Shanghai Composite Index. SICOMP: Shenzhen Component Index. NER: Nominal exchange rate. RER: Real exchange rate. TWEER: Trade-weighted effective exchange rate.

Table 4.4: Two-factor model for measuring industry level exposure (NER)

Industry returns	NER	L.NER	AIC	BIC
AFHF	-0.240[.903]	-161.721[.141]	-291.534	-281.490
Building construction	2.042[.257]	-191.820[.242]	-303.334	-293.2906
Chemicals	2.241[.298]	-63.241[.431]	-286.518	-276.475
Coal and petroleum	2.261[.380]	-50.529[.548]	-267.808	-257.764
Commercial Chains	1.208[.559]	-25.711[.775]	-300.250	-290.207
Communication	1.670[.416]	-60.64[.431]	-302.202	-292.159
Computer	1.603[.488]	-36.777[.605]	-287.631	-277.588
Construction materials	3.523[.150]	-90.615[.262]	-259.842	-249.799
Electrical equipment	2.237[.295]	-32.710[.691]	-296.513	-286.469
Electronic information	3.654[.131]	-62.382[.382]	-274.710	-264.667
Foreign trade	2.390[.410]	-45.254[.558]	-241.068	-231.024
Instruments and meters	2.863[.176]	-41.348[.544]	-297.550	-287.507
Machinery	3.248[.170]	-108.633[.163]	-279.166	-269.123
Medicine	1.934[.339]	-114.632[.149]	-309.246	-299.203
Non-ferrous metals	2.719[.346]	-104.418[.165]	-238.592	-228.549
Paper-making and printing	2.239[.350]	-55.562[.515]	-273.015	-262.971
Steel	2.355[.348]	-65.907[.429]	-260.306	-250.262
Textile and garment	3.002[.179]	-129.543[.142]	-276.867	-266.824
Tourism and hotel	3.465[.110]	-34.695[.695]	-294.793	-284.749
Transportation facilities	3.233[.103]	-79.377[.360]	-303.051	-293.008
Transport & logistics	2.106[.351]	-80.252[.330]	-283.025	-272.982
Vehicles	3.386[.154]	-89.989[.256]	-276.739	-266.695
Wine and food	1.348[.450]	-93.753[.239]	-319.46	-309.417
Other industries	3.047[.194]	-81.725[.244]	-275.405	-265.362

Notes:

The table above reports exposure estimates of industry returns to the change in the NER based on equation (4.4). Column 2 and 3 are the parameters for the changes in the NER and the lagged NER, respectively. The last two columns give values for information criteria. AIC: Akaike information criterion. BIC: Bayesian information criterion. P-values are reported in square brackets.

Table 4.5: Two-factor model for measuring industry level exposure (RER)

Industry returns	RER	L.RER	AIC	BIC
AFHF	2.801[.001]	-26.590[.355]	-298.895	-288.852
Building construction	2.435[.004]	-22.440[.402]	-306.171	-296.127
Chemicals	2.621[.004]	-16.329[.604]	-292.889	-282.846
Coal and petroleum	2.831[.005]	-22.075[.370]	-275.578	-265.534
Commercial chains	1.775[.035]	-12.769[.671]	-304.375	-294.331
Communication	2.071[.015]	-38.379[.189]	-307.795	-297.752
Computer	2.192[.013]	0.851[.977]	-292.465	-282.422
Construction materials	2.860[.009]	-18.947[.515]	-263.527	-253.483
Electrical equipment	1.505[.072]	11.891[.664]	-298.258	-288.215
Electronic information	3.562[.000]	-2.802[.923]	-284.480	-274.436
Foreign trade	3.590[.001]	2.028[.942]	-249.375	-239.331
Instruments and meters	2.543[.003]	-21.756[.393]	-304.311	-294.268
Machinery	2.455[.012]	-13.772[.596]	-279.649	-269.605
Medicine	2.583[.001]	15.178[.597]	-315.518	-305.475
Non-ferrous metals	3.267[.005]	-2.295[.927]	-242.119	-232.076
Paper-making and printing	3.093[.001]	14.087[.637]	-282.038	-271.994
Steel	2.808[.006]	-2.892[.916]	-265.762	-255.719
Textile and garment	3.190[.001]	-28.129[.369]	-284.287	-274.244
Tourism and hotel	2.263[.010]	-29.041[.291]	-299.496	-289.452
Transportation facilities	2.525[.002]	-7.097[.826]	-308.132	-298.088
Transport & logistics	2.265[.013]	5.252[.849]	-286.428	-276.385
Vehicles	3.042[.001]	-2.018[.945]	-282.040	-271.997
Wine and food	1.277[.106]	-23.232[.418]	-320.255	-310.212
Other industries	2.976[.002]	-29.913[.292]	-281.954	-271.910

Notes:

The table above reports exposure estimates of industry returns to the change in the RER based on equation (4.4). Column 2 and 3 are the parameters for the changes in the RER and the lagged RER, respectively. The last two columns give values for information criteria. AIC: Akaike information criterion. BIC: Bayesian information criterion. P-values are reported in square brackets.

Table 4.6: Two-factor model for measuring industry level exposure (TWEER)

Industry returns	TWEER	L.TWEER	AIC	BIC
AFHF	-0.490[.606]	65.748[.221]	-294.766	-284.722
Building construction	-1.620[.072]	26.737[.338]	-302.349	-292.305
Chemicals	-2.108[.022]	50.806[.159]	-296.173	-286.129
Coal and petroleum	-2.030[.056]	-2.471[.220]	-280.105	-270.062
Commercial chains	-2.120[.012]	50.650[.203]	-313.087	-303.043
Communication	-1.454[.085]	61.950[.117]	-311.908	-301.864
Computer	-1.130[.232]	47.211[.255]	-293.512	-283.468
Construction materials	-2.454[.025]	47.775[.180]	-267.720	-257.676
Electrical equipment	-2.107[.017]	29.913[.219]	-303.787	-293.744
Electronic information	-1.621[.113]	49.367[.147]	-280.063	-270.019
Foreign trade	-2.219[.073]	27.226[.271]	-245.810	-235.767
Instruments and meters	-1.671[.058]	61.274[.221]	-307.616	-297.573
Machinery	-2.136[.032]	40.045[.191]	-283.244	-273.200
Medicine	-0.961[.258]	49.069[.268]	-310.833	-300.790
Non-ferrous metals	-3.748[.002]	18.247[.454]	-246.227	-236.184
Paper-making and printing	-1.351[.176]	68.766[.211]	-283.720	-273.677
Steel	-2.271[.037]	20.011[.415]	-264.419	-254.376
Textile and garment	-1.411[.161]	52.701[.151]	-279.834	-269.790
Tourism and hotel	-1.907[.030]	50.661[.440]	-302.687	-292.644
Transportation facilities	-1.449[.097]	41.091[.110]	-305.939	-295.896
Transport & logistics	-1.766[.068]	40.847[.196]	-288.845	-278.801
Vehicles	-2.435[.014]	38.900[.124]	-282.327	-272.284
Wine and food	-1.297[.087]	68.222[.210]	-330.226	-320.182
Other industries	-1.642[.112]	49.789[.360]	-280.572	-270.528

Notes:

The table above reports exposure estimates of industry returns to the change in the TWEER based on equation (4.4). Column 2 and 3 are the parameters for the changes in the TWEER and the lagged TWEER, respectively. The last two columns give values for information criteria. AIC: Akaike information criterion. BIC: Bayesian information criterion. P-values are reported in square brackets.

Table 4.7: Market model for measuring industry level exposure (NER)

Industry returns	NER	L.NER	Market returns	AIC	BIC
AFHF	-1.838[.060]	-190.724[.204]	0.960[.000]	-413.824	-401.269
Building construction	-0.006[.994]	-66.60[.378]	0.981[.000]	-475.431	-462.876
Chemicals	-0.193[.803]	-296.502[.575]	1.100[.000]	-456.365	-438.789
Coal and petroleum	-0.904[.403]	-132.626[.198]	1.131[.000]	-402.202	-389.647
Commercial chains	-1.492[.146]	-63.017[.428]	0.925[.000]	-423.436	-410.882
Communication	-0.848[.358]	-77.500[.207]	0.934[.000]	-438.124	-425.57
Computer	-1.254[.288]	-42.989[.488]	0.966[.000]	-399.341	-386.786
Construction materials	0.259[.831]	-56.645[.436]	1.219[.000]	-421.180	-408.625
Electrical equipment	-0.751[.383]	-97.414[.800]	0.957[.000]	-436.980	-419.404
Electronic information	1.005[.218]	1358037[.200]	1.156[.000]	-428.713	-413.648
Foreign trade	-1.202[.335]	21.078[.954]	1.327[.000]	-433.089	-415.513
Instruments and meters	0.069[.952]	52.615[.453]	0.916[.000]	-410.124	-397.570
Machinery	0.644[.345]	-128.849[.189]	1.139[.000]	-488.570	-476.016
Medicine	0.161[.883]	16.648[.795]	0.857[.000]	-413.944	-401.389
Non-ferrous metals	-0.438[.671]	-161.679[.214]	1.376[.000]	-405.503	-392.949
Paper-making and printing	-0.497[.500]	-428.312[.128]	1.111[.000]	-443.547	-425.971
Steel	-1.329[.189]	3.982[.957]	1.236[.000]	-441.367	-428.813
Textile and garment	0.607[.390]	-320.130[.139]	1.106[.000]	-454.092	-436.516
Tourism and hotel	0.569[.494]	-304.186[.077]	1.009[.000]	-448.913	-431.337
Transportation facilities	0.635[.500]	-0.217[.815]	0.939[.000]	-446.690	-434.135
Transport & logistics	-0.702[.357]	-48.824[.579]	1.066[.000]	-447.832	-430.256
Vehicles	0.657[.424]	-138.926[.125]	1.121[.000]	-440.185	-422.609
Wine and food	-1.046[.306]	19.125[.776]	0.822[.000]	-433.557	-421.003
Other industries	0.244[.803]	-66.262[.292]	1.109[.000]	-429.266	-416.712

Notes:

The table above reports exposure estimates of industry returns to the change in the NER based on equation (4.5). Column 2 and 3 are the parameters for the changes in the NER and the lagged NER, respectively. The last two columns give values for information criteria. AIC: Akaike information criterion. BIC: Bayesian information criterion. P-values are reported in square brackets. ARCH effects are found in the linear regression test, hence one ARCH and one GARCH term are included in the DCC MGARCH test, namely chemicals, electronic equipment, foreign trade, paper-making and printing, tourism and hotel, transportation&logistics and vehicles.

Table 4.8: Market model for measuring industry level exposure (RER)

Industry returns	RER	L.RER	Market returns	AIC	BIC
AFHF	0.706[.137]	-39.314[.423]	0.939[.000]	-406.276	-388.700
Building construction	-0.075[.829]	-70.704[.212]	0.971[.000]	-480.142	-467.588
Chemicals	0.386[.204]	-226.022[.000]	1.120[.000]	-463.455	-445.879
Coal and petroleum	0.039[.943]	-36.697[.160]	1.090[.000]	-401.261	-388.707
Commercial chains	-0.537[.250]	-71.610[.153]	0.920[.000]	-425.042	-412.487
Communication	-0.278[.519]	-24.900[.441]	0.923[.000]	-436.862	-424.307
Computer	-0.217[.683]	-18.967[.506]	0.962[.000]	-398.488	-385.934
Construction materials	0.020[.968]	-54.158[.245]	1.219[.000]	-424.980	-412.426
Electrical equipment	-0.919[.033]	7.061[.817]	0.982[.000]	-432.022	-419.468
Electronic information	0.724[.128]	-177.580[.300]	1.111[.000]	-424.060	-406.484
Foreign trade	0.042[.922]	-76.526[.383]	1.305[.000]	-432.521	-414.945
Instruments and meters	0.308[.535]	-35.232[.207]	0.897[.000]	-411.426	-398.872
Machinery	-0.144[.672]	-92.299[.204]	1.170[.000]	-495.217	-482.663
Medicine	0.531[.266]	-12.900[.683]	0.839[.000]	-415.269	-402.715
Non-ferrous metals	-0.156[.767]	-35.902[.169]	1.388[.000]	-400.952	-388.398
Paper-making and printing	0.645[.051]	358.713[.001]	1.077[.000]	-447.295	-429.719
Steel	-0.244[.558]	-9.798[.746]	1.234[.000]	-439.880	-427.326
Textile and garment	0.357[.314]	-203.754[.000]	1.097[.000]	-458.751	-441.175
Tourism and hotel	-0.205[.625]	-25.906[.323]	0.984[.000]	-441.579	-429.025
Transportation facilities	0.179[.655]	-0.145[.704]	0.936[.000]	-446.639	-434.084
Transport & logistics	-0.620[.101]	-163.284[.220]	1.066[.000]	-454.800	-437.224
Vehicles	0.393[.362]	-48.192[.109]	1.110[.000]	-439.565	-427.011
Wine and food	-0.762[.083]	-48.281[.152]	0.839[.000]	-439.063	-426.509
Other industries	0.208[.646]	-48.389[.122]	1.083[.000]	-430.79	-418.236

Notes:

The table above reports exposure estimates of industry returns to the change in the RER based on equation (4.5). Column 2 and 3 are the parameters for the changes in the RER and the lagged RER, respectively. The last two columns give values for information criteria. AIC: Akaike information criterion. BIC: Bayesian information criterion. P-values are reported in square brackets. The following industries have been included one ARCH and one GARCH term in the DCC MGARCH test, including AFHF, chemicals, electronic information, foreign trade, paper-making and printing, tourism and hotel, transportation&logistics, and vehicles.

Table 4.9: Market model for measuring industry level exposure (TWEER)

Industry returns	TWEER	L.TWEER	Market returns	AIC	BIC
AFHF	0.943[.065]	13.472[.690]	0.969[.0000]	-406.342	-388.766
Building construction	0.162[.629]	44.802[.082]	0.993[.000]	-477.916	-465.362
Chemicals	-0.519[.145]	-10.277[.706]	1.030[.000]	-454.364	-436.788
Coal and petroleum	-0.903[.080]	27.192[.311]	1.085[.000]	-402.595	-390.039
Commercial chains	-0.822[.054]	-50.816[.105]	0.927[.000]	-426.040	-413.486
Communication	-0.122[.771]	40.006[.094]	0.889[.000]	-438.413	-425.858
Computer	0.300[.561]	-6.435[.820]	0.967[.000]	-398.334	-385.779
Construction materials	-0.628[.168]	-3.310[.902]	1.200[.000]	-422.405	-409.851
Electrical equipment	-0.511[.220]	-76.359[.740]	0.954[.000]	-437.570	-419.994
Electronic information	-0.032[.931]	-197.735[.058]	1.243[.000]	-423.366	-405.790
Foreign trade	0.169[.653]	-58.298[.580]	1.323[.000]	-432.291	-414.715
Instruments and meters	-0.561[.250]	-5.824[.837]	0.903[.000]	-410.832	-398.278
Machinery	-0.248[.441]	31.991[.188]	1.129[.000]	-486.782	-474.228
Medicine	0.412[.382]	-9.610[.723]	0.876[.000]	-414.717	-402.162
Non-ferrous metals	-1.208[.004]	-8.542[.875]	1.298[.000]	-407.112	-389.536
Paper-making and printing	-0.048[.893]	-108.044[.487]	1.120[.000]	-442.370	-424.794
Steel	0.025[.953]	7.404[.792]	1.225[.000]	-439.513	-426.958
Textile and garment	0.107[.751]	-5.070[.976]	1.119[.000]	-452.897	-435.321
Tourism and hotel	-0.331[.380]	-174.324[.012]	1.016[.000]	-448.588	-431.012
Transportation facilities	0.066[.877]	0.256[.554]	0.958[.00]	-446.733	-434.179
Transport & logistics	-0.022[.956]	-16.222[.565]	1.078[.000]	-445.351	-432.797
Vehicles	-0.316[.298]	-197.090[.002]	1.198[.000]	-450.095	-432.519
Wine and food	-0.196[.647]	38.327[.232]	0.771[.000]	-434.210	-421.656
Other industries	-0.213[.617]	-49.454[.128]	1.156[.000]	-430.374	-417.820

Notes:

The table above reports exposure estimates of industry returns to the change in the TWEER based on equation (4.5). Column 2 and 3 are the parameters for the changes in the TWEER and the lagged TWEER, respectively. The last two columns give values for information criteria. AIC: Akaike information criterion. BIC: Bayesian information criterion. P-values are reported in square brackets. The following industries have been included one ARCH and one GARCH term in the DCC MGARCH test, including AFHF, chemicals, electronic equipment, electronic information, foreign trade industries, non-ferrous metals, paper-making and printing, tourism and hotel, transportation&logistics and vehicles.

Table 4.10: Three-factor model for measuring industry level exposure (NER)

Industry returns	NER	L.NER	Market returns	AIC	BIC
AFHF	-2.972[.005]	-54.24[.280]	0.993[.000]	-411.223	-398.669
Building construction	-0.293[.773]	-112.806[.157]	1.003[.000]	479.598	-462.022
Chemicals	-0.783[.410]	-59.384[.397]	0.994[.000]	-453.638	-441.084
Coal and petroleum	-0.027[.981]	-44.877[.283]	1.010[.000]	-402.971	-390.416
Commercial chains	-2.125[.029]	114.974[.453]	1.001[.000]	-424.837	-407.261
Communication	-0.659[.486]	-72.356[.254]	1.006[.000]	-439.057	-426.503
Computer	-0.887[.446]	-35.299[.572]	1.008[.000]	-402.157	-389.603
Construction materials	0.824[.502]	-65.813[.375]	0.998[.000]	-407.633	-395.079
Electrical equipment	-0.881[.307]	-81.566[.809]	0.997[.000]	-436.888	-419.312
Electronic information	1.294[.187]	-141.643[.809]	1.001[.000]	-416.931	-399.355
Foreign trade	-0.023[.985]	-17.693[.800]	1.008[.000]	-390.382	-377.828
Instruments and meters	-0.281[.807]	57.518[.427]	1.000[.000]	-408.193	-395.639
Machinery	0.959[.204]	-141.322[.153]	1.001[.000]	-477.040	-464.486
Medicine	-0.352[.757]	35.465[.581]	1.001[.000]	-408.297	-395.743
Non-ferrous metals	0.022[.983]	-174.257[.103]	0.997[.000]	-376.399	-358.823
Paper-making and printing	0.280[.710]	-418.616[.120]	1.007[.000]	-443.499	-425.923
Steel	-0.846[.303]	-368.444[.111]	1.000[.000]	-430.243	-412.667
Textile and garment	0.758[.325]	-304.644[.287]	0.999[.000]	-449.660	-432.084
Tourism and hotel	0.655[.421]	-322.244[.124]	1.001[.000]	-448.965	-431.389
Transportation facilities	0.333[.732]	21.474[.798]	1.001[.000]	-445.278	-432.724
Transport & logistics	-0.558[.437]	-59.292[.544]	0.999[.000]	-446.226	-428.649
Vehicles	1.350[.120]	-134.505[.148]	1.005[.000]	-436.484	-418.9082
Wine and food	-2.006[.058]	32.639[.569]	0.993[.000]	-425.317	-412.762
Other industries	0.719[.476]	-72.293[.237]	1.003[.000]	-425.910	-413.355

Notes:

The table above reports exposure estimates of industry returns to the change in the NER based on equation (4.6). Column 2 and 3 are the parameters for the changes in the NER and the lagged NER, respectively. The last two columns gives values for information criteria. AIC: Akaike information criterion. BIC: Bayesian information criterion. P-values are reported in square brackets. The following industries have been included one ARCH and one GARCH term in the DCC MGARCH test, including building construction, commercial chains, electrical equipment, electronic information, non-ferrous metals, paper-making and printing, steel, textile and garment, transportation&logistics, and vehicles.

Table 4.11: Three-factor model for measuring industry level exposure (RER)

Industry returns	RER	L.RER	Market returns	AIC	BIC
AFHF	0.642[.165]	-29.756[.530]	0.996[.000]	-406.556	-388.979
Building construction	-0.114[.728]	-67.628[.212]	1.003[.000]	-480.474	-467.920
Chemicals	0.531[.083]	-116.597[.120]	0.999[.000]	-460.306	-442.730
Coal and petroleum	0.323[.517]	-43.258[.106]	1.010[.000]	-403.388	-390.834
Commercial chains	-0.718[.110]	-61.641[.182]	1.002[.000]	-423.274	-410.720
Communication	-0.494[.220]	1.122[.971]	1.007[.000]	-438.587	-426.033
Computer	-0.277[.568]	-8.264[.769]	1.009[.000]	-401.726	-389.172
Construction materials	0.631[.227]	-61.456[.241]	0.998[.000]	-411.203	-398.648
Electrical equipment	-0.957[.019]	5.658[.851]	0.998[.000]	-432.131	-419.577
Electronic information	1.098[.022]	-168.119[.301]	1.003[.000]	-421.624	-404.048
Foreign trade	1.068[.037]	-18.577[.584]	1.008[.000]	-395.453	-382.898
Instruments and meters	0.039[.936]	-31.771[.267]	0.999[.000]	-408.759	-396.204
Machinery	0.230[.530]	-69.247[.112]	1.000[.000]	-476.563	-464.009
Medicine	0.139[.770]	-26.261[.394]	1.001[.000]	-408.715	-396.160
Non-ferrous metals	0.290[.531]	-145.919[.202]	0.997[.000]	-380.495	-362.919
Paper-making and printing	0.655[.137]	-2.966[.909]	1.009[.000]	-423.423	-410.868
Steel	0.345[.424]	-9.669[.750]	1.005[.000]	-423.812	-411.257
Textile and garment	0.492[.185]	-205.685[.209]	1.000[.000]	-455.246	-437.670
Tourism and hotel	-0.243[.544]	-24.573[.346]	1.000[.000]	-441.492	-428.937
Transportation facilities	0.058[.882]	-21.815[.502]	1.001[.000]	-445.468	-432.914
Transport & logistics	-0.491[.182]	-165.724[.106]	1.000[.000]	-452.937	-435.361
Vehicles	0.696[.101]	-42.150[.173]	1.004[.000]	-436.162	-423.608
Wine and food	-1.239[.003]	-33.421[.286]	0.995[.000]	-432.187	-419.633
Other industries	0.424[.333]	-59.720[.254]	1.002[.000]	-429.048	-416.494

Notes:

The table above reports exposure estimates of industry returns to the change in the RER based on equation (4.6). Column 2 and 3 are the parameters for the changes in the RER and the lagged RER, respectively. The last two columns give values for information criteria. AIC: Akaike information criterion. BIC: Bayesian information criterion. P-values are reported in square brackets. The following industries have been included one ARCH and one GARCH term in the DCC MGARCH test, including AFHF, chemicals, commercial chains, electronic information, non-ferrous metals, paper-making and printing, steel, textile and garment, transportation&logistics, and vehicles.

Table 4.12: Three-factor model for measuring industry level exposure (TWEER)

Industry returns	TWEER	L.TWEER	Market returns	AIC	BIC
AFHF	0.569[.198]	-124.139[.243]	0.993[.000]	-411.861	-394.285
Building construction	0.159[.625]	50.333[.253]	1.004[.000]	-479.218	-466.664
Chemicals	-0.512[.172]	16.753[.585]	0.995[.000]	-453.669	-441.115
Coal and petroleum	-1.065[.032]	19.605[.450]	1.010[.000]	-404.424	-391.870
Commercial chains	-0.831[.003]	-180.832[.000]	1.004[.000]	-433.459	-415.883
Communication	0.033[.935]	22.980[.333]	1.007[.000]	-437.956	-425.401
Computer	0.328[.501]	-14.178[.608]	1.009[.000]	-402.095	-389.540
Construction materials	-0.920[.057]	21.831[.405]	0.998[.000]	-412.108	-399.554
Electrical equipment	-1.071[.019]	-16.718[.159]	0.995[.000]	-409.198	-391.622
Electronic information	-0.138[.746]	7.031[.966]	1.001[.000]	-415.335	-397.759
Foreign trade	-0.527[.332]	14.981[.567]	1.008[.000]	-392.036	-379.482
Instruments and meters	-0.407[.388]	-20.643[.422]	0.999[.000]	-408.683	-396.129
Machinery	-0.435[.193]	44.812[.043]	0.999[.000]	-477.572	-465.018
Medicine	0.681[.137]	-21.677[.399]	1.000[.000]	-410.677	-398.123
Non-ferrous metals	-1.944[.001]	5.808[.823]	0.998[.000]	-381.575	-369.020
Paper-making and printing	-0.237[.513]	20.911[.890]	1.006[.000]	-442.150	-424.574
Steel	-0.821[.056]	230.785[.205]	1.000[.000]	-433.548	-415.972
Textile and garment	-0.063[.849]	93.160[.386]	0.998[.000]	-448.418	-430.842
Tourism and hotel	-0.384[.261]	-175.212[.115]	1.000[.000]	-448.685	-431.109
Transportation facilities	0.296[.404]	-52.728[.258]	1.001[.000]	-448.695	-436.141
Transport & logistics	-0.275[.357]	-51.545[.299]	1.000[.000]	-447.013	-429.437
Vehicles	-0.817[.016]	-174.562[.165]	1.004[.000]	-438.053	-420.477
Wine and food	0.130[.764]	-24.064[.462]	0.995[.000]	-422.514	-409.959
Other industries	-0.373[.421]	-11.678[.699]	1.002[.000]	-424.819	-412.264

Notes:

The table above reports exposure estimates of industry returns to the change in the TWEER based on equation (4.6). Column 2 and 3 are the parameters for the changes in the TWEER and the lagged TWEER, respectively. The last two columns give values for information criteria. AIC: Akaike information criterion. BIC: Bayesian information criterion. P-values are reported in square brackets. The following industries have been included one ARCH and one GARCH term in the DCC MGARCH test, including AFHF, chemicals, commercial chains, electronic equipment, electronic information, non-ferrous metals, paper-making and printing, steel, textile and garment, transportation&logistics, and vehicles.

Table 4.13: Exchange rate exposure at the industry level

	Two-factor model			Market model			Three-factor model(excess return)		
	NER	RER	TWEER	NER	RER	TWEER	NER	RER	TWEER
AFHF	0.162	2.863	-1.272	-2.977	0.783	0.879	-3.380	0.121	0.903
	(0.01)	(11.29)***	(1.93)	(6.99)***	(2.88)*	(3.56)*	(9.15)***	(0.07)	(3.75)*
Building construction	2.894	2.456	-1.846	-0.284	0.048	0.154	-0.421	0.012	0.164
	(2.05)	(9.05)***	(4.65)**	(0.13)	(0.02)	(0.21)	(0.30)	(0.000)	(0.25)
Chemicals	2.428	2.534	-2.573	-0.450	0.531$^\diamond$	-0.518	-1.074	0.230	-0.518
	(1.24)	(8.36)***	(8.18)***	(0.26)	(3.01)*	(2.10)	(1.05)	(0.37)	(2.10)
Coal and petroleum	2.892	2.944	-3.030	-0.681	0.265	-0.855	0.090	0.502	-1.043
	(1.45)	(9.28)***	(9.36)***	(0.33)	(0.27)	(2.84)*	(0.01)	(1.08)	(4.61)**
Commercial chains	1.304	1.755	-2.573	-1.639	-0.498	-0.809	-1.895	-0.508	-0.831$^\diamond$
	(0.42)	(4.56)**	(9.81)***	(2.54)	(1.22)	(3.26)*	(3.82)**	(1.79)	(8.62)***
Communication	1.994	1.939	-1.946	-1.001	-0.355	-0.090	-0.886	-0.504	0.046
	(0.99)	(5.63)**	(5.38)**	(1.10)	(0.73)	(0.05)	(0.86)	(1.67)	(0.01)
Computer	1.944	2.163	-1.631	-1.148	-0.183	0.309	-0.855	-0.278	0.356
	(0.81)	(6.07)**	(3.18)*	(0.96)	(0.13)	(0.36)	(0.55)	(0.34)	(0.53)
Construction materials	3.075	2.706	-3.043	-0.211	-0.301	-0.629	0.399	0.260	-1.020
	(2.15)	(6.89)***	(8.41)***	(0.04)	(0.44)	(1.95)	(0.13)	(0.32)	(4.86)**
Electrical equipment	2.478	1.530	-2.360	-0.747	-0.865	-0.518	-0.888	-0.917	-1.033
	(1.46)	(3.24)*	(7.76)***	(0.77)	(4.09)**	(1.51)	(1.08)	(5.12)**	(5.04)**
Electronic information	4.277	3.560	-2.302	0.918	0.518	0.049	1.288	0.826	-0.147
	(3.40)*	(15.10)***	(5.46)**	(1.02)	(1.45)	(0.01)	(1.77)	(3.32)*	(0.12)
Foreign trade	2.868	3.564	-2.620	-1.125	0.062	0.167	0.016	1.122	-0.628
	(1.06)	(10.29)***	(5.01)**	(1.29)	(0.02)	(0.18)	(0.00)	(5.16)**	(1.48)
Instruments and meters	3.131	2.499	-2.357	0.196	0.290	-0.546	-0.110	0.053	-0.338
	(2.35)	(9.16)***	(7.63)***	(0.03)	(0.36)	(1.29)	(0.01)	(0.01)	(0.52)

Notes:

1. The exchange rate exposure of industry returns is modelled in the form of equations (4.4)-(4.6) separately. This table shows exposure betas with Wald tests estimated by industry.
2. The econometric strategy for measuring exchange rate exposure is the DCC GARCH model (see equation (4.7)). Each model has been carried out a single ARCH test before using the DCC GARCH approach. If homoscedasticity of error terms $\varepsilon_{j,t}$ in the linear regression test is rejected , the GARCH(1,1) process will be included in the disturbance of the variances. Otherwise, only the mean model will be estimated. None of the linear regression tests have ARCH effects based on the two-factor model estimates. For the market model, the following industries (different types of exchange rates are in included) have been included one ARCH and one GARCH term in the DCC GARCH test: AFHF (RER&TWEER), chemicals (NER, RER&TWEER), electrical equipment (NER&TWEER), electronic information (NER, RER&TWER) and foreign trade (NER, RER&TWEER). For the three-factor model, the following industries have been incorporated in one ARCH and one GARCH term: AFHF (RER&TWEER), building construction (NER), chemicals (RER&TWEER), commercial chains (NER, RER&TWEER), electrical equipment (NER&TWEER), electronic information (NER, RER&TWEER).
3. Numbers in parentheses are Wald test results. $\diamond$ suggests that lagged exchange rate variables are included in the model.
4. ***,** and * indicate the significance at the 1%, 5% and 10% levels, respectively.

Table 4.13 *continued*

	Two-factor model			Market model			Three-factor model(excess return)		
	NER	RER	TWEER	NER	RER	TWEER	NER	RER	TWEER
Machinery	4.523	2.361	-2.580	0.846	-0.509	-0.272	1.316	-0.085	-0.560
	(3.93)**	(6.26)**	(7.17)***	(1.35)	(2.63)	(0.73)	(2.83)*	(0.07)	(2.89)*
Medicine	2.941	2.571	-1.35	0.199	0.532	0.401	-0.243	0.126	0.665
	(2.31)	(11.03)***	(2.66)	(0.03)	(1.31)	(0.73)	(0.05)	(0.08)	(2.03)
Non-ferrous metals	4.127	3.276	-4.028	-0.282	-0.083	-1.247	-0.083	0.426	-1.822
	(2.10)	(8.03)***	(12.00)***	(0.06)	(0.03)	(9.22)***	(0.01)	(0.66)	(20.60)***
Paper-making and printing	2.569	3.091	-2.294	-0.488	0.645◇	-0.044	0.246	0.821	-0.239
	(1.21)	(11.03)***	(5.46)**	(0.38)	(3.81)*	(0.01)	(0.10)	(5.62)**	(0.44)
Steel	2.730	2.797	-2.449	-1.231	-0.211	0.016	-0.753	-0.004	-0.749
	(1.18)	(7.58)***	(5.41)**	(1.74)	(0.27)	(0.00)	(0.84)	(0.00)	(3.48)*
Textile and garment	3.719	3.224	-1.903	0.354	0.362	0.107	0.502	0.563	-0.079
	(2.59)	(12.24)***	(3.73)*	(0.26)	(0.96)	(0.10)	(0.44)	(2.14)	(0.06)
Tourism and hotel	3.630	2.252	-2.270	0.569◇	0.223	-0.390	0.466	0.049	-0.384
	(3.07)*	(7.02)***	(6.76)***	(0.47)	(0.00)	(1.11)	(0.25)	(0.02)	(1.26)
Transportation facilities	3.622	2.503	-1.773	0.606	0.214	0.141	0.441	0.057	0.243
	(3.32)*	(9.67)***	(4.37)**	(0.45)	(0.30)	(0.13)	(0.23)	(0.02)	(0.40)
Transportation & logistics	2.718	2.225	-2.180	-0.745	-0.573	-0.123	-0.637	-0.466	-0.233
	(1.50)	(6.01)**	(5.45)**	(0.79)	(2.00)	(0.10)	(0.55)	(1.24)	(0.38)
Vehicles	4.213	3.003	-2.731	0.553	0.195	-0.540	1.473	0.602	-0.817
	(3.34)*	(10.41)***	(8.00)***	(0.30)	(0.23)	(1.94)	(2.44)	(2.49)	5.76**
Wine and food	1.678	1.183	-1.862	-0.955	-0.889	-0.243	-1.848	-1.265	0.172
	(0.85)	(2.45)	(5.99)**	(0.97)	(4.63)**	(0.33)	(3.29)*	(9.76)***	(0.16)
Other industries	3.696	9.85	-2.315	0.127	0.241	-0.077	0.612	0.492	-0.305
	(2.54)	(9.85)***	(5.58)**	(0.02)	(0.31)	(0.03)	(0.36)	(1.39)	(0.50)

Notes:

1.The exchange rate exposure of industry returns is modelled in the form of equations (4.4)-(4.6) separately. This table shows exposure betas with Wald tests estimated by industry.

2. The econometric strategy for measuring exchange rate exposure is the DCC GARCH model (see equation (4.7)). Each model has been examined the ARCH effect before using the DCC GARCH approach. For the market model, the following industries have been incorporated in one ARCH and one GARCH term: non-ferrous Metals (TWEER), paper-making and printing (NER, RER&TWEER), tourism and hotel (NER, RER&TWEER), transportation and logistics (NER, RER&TWEER) and vehicles (NER, RER&TWEER). For the three-factor model, the following industries have been incorporated in one ARCH and one GARCH term: non-ferrous metals (NER, RER&TWEER), paper-making and printing (NER, RER&TWER), steel (NER, RER&TWEER), textile and garment (NER, RER&TWEER), tourism and hotel (NER, RER&TWEER), transportation&logistics (NER, RER&TWEER) and vehicles (NER, RER&TWEER). Except these cases above, only the mean model is estimated in the remaining industries based on different theoretical models and exchange rate variables.

3. Numbers in parentheses are Wald test results. ◇ suggests that lagged exchange rate variables are included in the model.

4. ***,** and * indicate the significance at the 1%, 5% and 10% levels, respectively.

Table 4.14: Summary statistics of exposure betas for industries

		Mean	Median	StdDev	N^{+}(%)	N^{-}(%)
Two-factor model	NER	2.901	2.893	1.023	6(25%)	0(0)
	RER	2.869	2.553	1.602	23(95.83%)	0(0)
	TWEER	-2.308	-2.309	0.589	0(0)	22(91.67%)
Market model	NER	-0.400	-0.367	0.902	0(0)	1(4.17%)
	RER	0.019	0.129	0.467	3(12.5%)	2(8.33%)
	TWEER	-0.195	-0.107	0.465	1(4.17%)	3(12.5%)
Three-factor model	NER	-0.259	-0.097	1.110	1(4.17%)	3(12.5%)
	RER	0.093	0.089	0.559	3(12.5%)	2(8.33%)
	TWEER	-0.346	-0.322	0.604	1(4.17%)	8(33.33%)

Notes:

1. Data Source: Author's Calculation referring to Table 4.13.
2. N^{+} and N^{+} designate the number of significant positive and negative exposure coefficients, respectively. Numbers in parentheses are the percentages of significant betas that account for the total number of industries (24).

Figure 4.1: Stock market indexes and exchange rate indexes

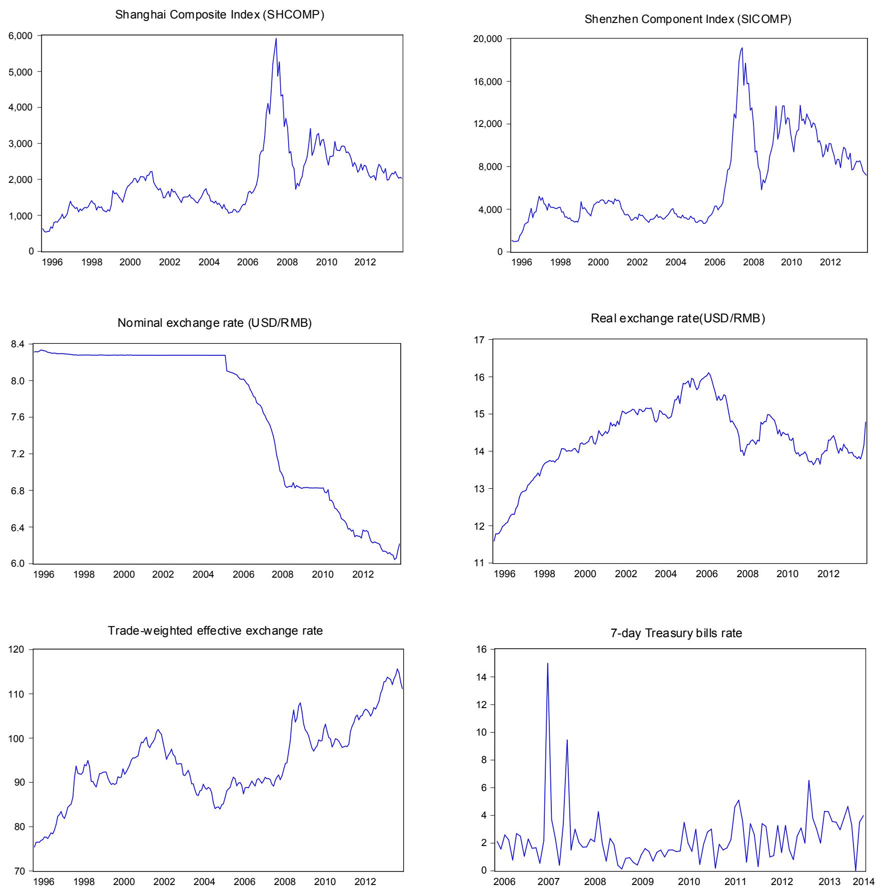


Table 4.15: Exchange rate exposure at the firm level

	Two-factor model			Market model		
	NER	RER	TWEER	NER	RER	TWEER
SHA$_{larle}$	0.106	-0.400	-0.059	0.099	-0.397	-0.063
SHA$_{medium}$	0.253	-0.188	-0.346	0.257	-0.227	-0.340
SHA$_{small}$	0.429**	0.163	-0.261	0.399**	0.146	-0.260
F-test$_{SHA}$	1.54	5.49*	1.06	1.10	5.65*	1.07
SHB$_{large}$	0.569*	0.401	-0.909***	0.599*	0.405	-0.927***
SHB$_{medium}$	0.865**	0.327	-0.973**	0.816*	0.273	-0.932**
SHB$_{small}$	0.646	0.722	-1.033	0.460	0.585	-0.977
F-test$_{SHB}$	0.48$^{\diamond}$	0.19$^{\diamond}$	0.04$^{\diamond}$	0.27$^{\diamond}$	0.13	0.00$^{\diamond}$
SZA$_{large}$	1.151	0.526	-1.939*	0.505	0.133	-1.015***
SZA$_{medium}$	-0.179	-0.453**	-0.014$^{\spadesuit}$	-0.221	-0.481***	0.013$^{\spadesuit}$
SZA$_{small}$	-0.017	-0.265	0.832$^{\spadesuit}$	-0.115	-0.331	0.243
F-test$_{SZA}$	1.96	1.27	9.01**	19.50***	9.05**	36.28***
SZB$_{large}$	-0.267	-0.477	-0.020	-0.221	-0.452	-0.070
SZB$_{medium}$	0.299$^{\spadesuit}$	-0.065	-0.256$^{\spadesuit}$	0.283$^{\spadesuit}$	-0.094	-0.192$^{\spadesuit}$
SZB$_{small}$	0.606	0.356	-0.393	0.591	0.324	-0.280
F-test$_{SZB}$	4.80 *	2.82	0.59$^{\diamond}$	4.68$^{\diamond}$ *	2.97$^{\diamond}$	0.19
SHSE$_{large}$	0.165	-0.301	-0.143	0.162	-0.300	-0.145
SHSE$_{medium}$	0.367	-0.091	-0.448	0.373	-0.118	-0.444
SHSE$_{small}$	0.422**	0.215	-0.336	0.425**	0.202	-0.335
F-test$_{SHSE}$	0.87	3.14	1.52	1.02	3.09	1.57
SZSE$_{large}$	0.700	0.172	-1.346**	0.893	0.149	-1.513**
SZSE$_{medium}$	-0.113	-0.414**	-0.045$^{\spadesuit}$	-0.085	-0.418**	-0.071$^{\spadesuit}$
SZSE$_{small}$	0.021	-0.231	0.012$^{\spadesuit}$	0.069	-0.238	-0.029$^{\spadesuit}$
F-test$_{SZSE}$	1.88	1.45	7.19**	2.86	1.50	9.75***
SHSZ$_{large}$	0.309	-0.175	-0.519$^{\spadesuit}$	0.333	-0.193	-0.532$^{\spadesuit}$
SHSZ$_{medium}$	0.129	-0.266	-0.282$^{\spadesuit}$	0.177	-0.245	-0.293$^{\spadesuit}$
SHSZ$_{small}$	0.106	-0.163	0.016$^{\spadesuit}$	0.113	-0.173	0.012$^{\spadesuit}$
F-test$_{SHSZ}$	1.81	0.96	7.87**	1.83	0.97	8.45**
			(7.36)**			(7.69)**

Notes:

1. This table reports the firm level exposure estimated from equation (4.4) and equation (4.5). The three-factor model is not estimated due to the very small number of observations.
2. Exposure coefficient variations across firms are indicated by the F-tests. For example, the null hypothesis of the exposure betas estimated from the Shanghai A-share market: $\beta_{SHA_{large}} = \beta_{SHA_{medium}} = \beta_{SHA_{small}}$, if the null is rejected, it indicates that there is a correlation between firm size and exchange rate exposure.
3. $\diamond$ designates that there is no cross-equation contemporaneous correlation in the residuals, thus each equation estimated by the SUR is equivalent to the OLS estimates.
4. $\spadesuit$ indicates that the exposure beta of the lagged exchange rate variable is statistically significant, although the level exchange rate variable is insignificant. Numbers in parentheses report the Wald test for the lagged exchange rate variable.
5. ***,** and * indicate the significance at the 1%, 5% and 10% levels, respectively.

Chapter 5

Conclusions

5.1 Thesis Background

Since China's reform and opening up in 1978, the international community has been closely concerning about the expansion of China' exports and the increased interactions between the Chinese economy and the global economy. One of the concerns about the Chinese economy is the managed floating RMB exchange rate policy. As the international community believes that the Chinese currency policy has benefited the Chinese economy but has harmed trade partners' growth. Therefore, they are increasingly pressing the Chinese authorities to allow RMB to be more tradeable and flexible in the foreign exchange market. Actually, the daily floating range of RMB against USD has been widened from 0.3% in 1994 to 2% in 2014, but the pressure on RMB appreciation is still growing. However, is the Chinese economy closely associated with its currency policy? This question is of interest to academics, policy-makers and investors. Although some of the RMB exchange rate topics have been explored in the existing literature, the long run equilibrium and short run dynamics between RER and economic growth in China remain unanswered. In addition, existing studies on the dynamic correlation between the Chinese stock market and foreign exchange market are mainly focused on the aggregate market (the Shanghai or the Shenzhen market), but the evidence from both RMB ordinary shares and foreign capital shares are commonly ignored in those studies. Furthermore, in spite of the fact that a very small number of studies have addressed the RMB exchange rate risks, the exchange rate exposure of Chinese firms are unsatisfactorily explored, particularly for the industry and firm level exposure analyses. As a consequence, the research into the RMB exchange rate dynamics and risks is of theoretical and practical importance.

The main aim of this thesis is to investigate exchange rate dynamics and risks in China based on empirical evidence. It consists of three empirical chapters and two of them discuss the dynamics of the RMB exchange rate, and the third one analyses the exchange rate exposure of Chinese firms. Specifically, Chapter 2 explores the correlation between RER and economic growth in China since 1994. Chapter 3 gives the empirical analysis of spillover effects between exchange rate changes and stock returns in the Chinese financial market. Chapter 4 examines the exchange rate exposure of Chinese firms at both the industry and firm levels.

To unlock the secret of China's growth, the first empirical chapter assumes that the Chinese economy is related to the RMB exchange rate, then turns to the investigation of the long run equilibrium and short run dynamics between RER and economic growth. The data used in the first empirical chapter consist of the determinants of the RER, namely the RGDP, FER, imports, exports and FDI. To explore the long run equilibrium between RER and economic growth, the CVAR approach is applied to test the cointegration relationship. As the CVAR model requires that all the variables should be integrated I(1), four categories of stationary test methods are applied to test the unit roots of the variables. Among these methods, three of them are univariate unit root tests (ADF, KPSS and Ng-perron tests) and the remaining approach is the multivariate unit root test (Johansen test). These tests confirm the integration order of I(1) of the determinants, which indicates that the CVAR approach is appropriate for this chapter. Nevertheless, the CVAR model estimates show disparities in the number of cointegrating vectors based on the trace test and the max-eigenvalue test. In order to identify cointegrating vectors, the chapter mainly introduces the recursive test to examine the stationarity of those cointegration relationships.

Since the structural change of the 2005 RMB policy reform is commonly tested in the previous literature, Chapter 2 re-examines structural breaks of RMB policy changes. In consideration of the effect of the 2008 global financial crisis on the Chinese economy, the chapter also investigates the linkage between RER and economic growth using the same approach based on the post-crisis sample. This can be used to explain the stability of the long run equilibrium in the RER-growth correlation.

Next, based on the theory of "flow-oriented" exchange rate models and "stock-oriented" exchange rate models, Chapter 3 investigates spillover effects between exchange rate changes and stock returns in the Chinese financial market. The chapter starts with the examination of causality between stock markets and foreign exchange markets using a multivariate VAR approach. Taking into consideration structural innovations between exchange rate changes and stock returns, the chapter further models spillovers in the conventional SVAR approach. The SVAR model could be identified by imposing restrictions on short run parameters based on theoretical assumptions (see equation (3.11)). However, the short run restrictions in the SVAR model are usually counterintuitive and the normal assumption on the residuals is commonly invalid. Thus, the SVAR estimates are inadequate to interpret some of the shocks of interest. In order to address this issue, the chapter introduces the MS-SVAR approach to model spillover effects between exchange rate changes and stock returns, which captures the dynamic structure of the Chinese financial market. Concerning spillovers during financial crises, the subsamples of the 1997 Asian financial crisis and the 2008 world financial crisis are examined separately.

Finally, the last empirical chapter (Chapter 4) assumes that Chinese exporting firms are subject to exchange rate changes in spite of the ongoing managed floating exchange rate policy in China.[89] This chapter examines the exchange rate exposure of Chinese firms at both the industry and firm level, which are estimated by a macroeconometric approach and a microeconometric approach, respectively. Under the conventional CAPM framework, the industry level exposure analysis is explored applying the DCC MGARCH model, which is based on the capital market approach with a sample of 24 industry indexes from the Chinese stock market. This represents the exchange rate exposure of Chinese firms at the macro level. The firm level exposure analysis is carried out using the cash flow approach, which is estimated by the SUR model. This model is able to test the different exposure effects among different types of firms (large, medium and small firms). Since we do not know exactly which kind of exchange rate has the largest influence on Chinese firms, therefore, the changes in the NER, RER and TWEER are individually tested in this chapter. In addition, empirical studies demonstrate disparities in selecting models for measuring the exchange rate exposure. Thus, the two-factor model (equation (4.4)), market model (equation (4.5)) and three-factor model (equation (4.6)) for measuring exchange rate exposure are carried out separately to determine the best model. Considering lagged exchange rate exposure effects on Chinese firms, this chapter incorporates the lagged exchange rate variable into the theoretical framework.

In following sections, this chapter gives a brief summary of findings from the three empirical research chapters; discusses possible policy implications based on

[89] Due to the application of different datasets and research methods, the results from Chapter 3 and Chapter 4 are different. At the market level, exchange rate changes have no spillovers on stock returns. While at the industry and firm levels, industry and firm returns are subject to exchange rate changes due to their participation in global operations, in particular for those large firms.

the empirical analysis of exchange rate dynamics and risks in China; identifies the weakness of this research, and finally proposes several areas for future researches about RMB exchange rate dynamics and risks, as well as other interesting topics.

5.2 Summary of Findings

Chapter 2 explores the dynamic relationship between RER and economic growth in China applying a CVAR approach. The data used in this chapter cover the period January 1994 to December 2012. The cointegration estimates suggest that there are two cointegrating vectors in the system, they are the RER equation and growth equation. The identified two cointegrating vectors reveal the determinants of RER and what has contributed to China's growth, respectively. As revealed by the RER equation, exports and FDI have a positive impact on the RMB exchange rate in the long run, while FER and imports are negatively correlated with the RER. These determinants jointly maintain the stability of the Chinese currency. As equation (2.16) shows, a 1% increase in exports contributes to the depreciation of RER by 6.55%, but a 1% upturn in the imports leads to the appreciation of RER by 4.29%. Although the effects on the RMB exchange rate from FDI and FER are comparatively smaller than those of exports and imports, they still play a key role in determining the stability of the Chinese currency. Besides these determinants, the managed floating exchange rate policy might have affected the upturn and downturn of the Chinese currency, which is examined in the VECM. Equation (2.17) presents the growth equation. It implies that the main driving forces for the Chinese economy are the expansion of exports and inflow of foreign capital. Notice that a 1% increase in exports will increase RGDP by 17.84%, holding all other things constant. Added to that, a 1% upturn of the foreign capital results in the increase in RGDP by 10.30%. However, there is no direct nexus between RER and RGDP as revealed by the CVAR estimates. This means that the RMB policy change does not exhibit any significant impact on China's growth in the long run, but it might have temporary effects on the Chinese economy. This is proved by examining the short run dynamics between RER and economic growth. On the contrary, the fluctuation in the RGDP may have temporal impact on RER, but it cannot affect the long term change in the RER.

Additionally, the short run relationship between RER and economic growth estimated by the VECM reveals the existence of correlation between RER and RGDP. The RGDP equation shown in Table 2.10 indicates that RER is negatively correlated with RGDP. This suggests that the appreciation of the Chinese currency will lead to the decline of RGDP in the short run. In reality, the international community is increasingly pressing the Chinese government to appreciate the RMB since they believe that the lower RMB exchange rate has put trade partners in a disadvantaged situation. The Chinese authorities have to respond to the pressure and make appropriate adjustments to its currency policy, but the adjustments still cannot meet trade partners' expectations, since the speed of RMB appreciation is quite slow. In the VECM outputs, the error correction terms are very small but statistically significant. This indicates that the equilibrium between RGDP and the growth indicators need a relatively long period to return to normal state once there are any shocks to the growth equation. In addition to the analysis on the short run dynamics, the structural change of the 2005 RMB policy reform is examined. The coefficient of the dummy variable is statistically significant. This suggests that the RMB policy reform has some impact on the growth in the short run, but it did not show any significant impact on the RER. The structural break test for the 2005 RMB policy change is examined in the RER equation. This chapter concludes that there are no structural breaks in 2005 based on the Chow breakpoint test and the Quandt-Andrews test, which is consistent with previous findings (Shah et al., 2005; Zhiwen, 2011).

Chapter 2 further examines the relationship between RER and China's growth after the 2008 great recession. The empirical evidence shows that the growth in RGDP tends to appreciate the RMB after 2008, but the increase in FER helps to depreciate the RER. Nevertheless, exports and imports are exogenous in the identified cointegrating vector. This means that the equilibrium RMB exchange rate is not merely determined by foreign trade any more and their influences on RER are declining. By contrast, the cointegrating vector shows that inflow of foreign capital plays an important role in determining the RMB exchange rate. Intuitively, the cointegration graph looks much more stable (Figure 2.19) than the whole sample estimates (Figure 2.8), which indicates the remarkable adaptive of the Chinese currency under the managed floating exchange rate system.

To further observe the effects of exchange rate changes on the Chinese stock market, spillover effects between exchange rate changes and stock returns are investigated in Chapter 3. The sample covers the period 31 January 1994 to 31 December 2012. The subsamples of the 1997 Asian financial crisis and the 2008 global financial crisis are also examined. Following Dolado and Lütkepohl (1996), Ibrahim (2000), Phylaktis and Ravazzolo (2005), Chapter 3 applies the multivariate Granger causality test to investigate the casual relationship between exchange rate changes and stock returns. The results (see Table 3.3) show that there are no spillover effects from RMB ordinary share markets to foreign exchange markets ($SR_A \nRightarrow ER$), and exchange rate changes cannot Granger-cause stock returns, but foreign capital share returns have a significant impact on exchange rate changes, such as the SHBI, which has significant influences on the remaining stock returns and exchange rate changes ($SR_{SHBI} \Rightarrow ER$ and $SR_{SHBI} \Rightarrow SR$). This means that there is only a unidirectional relationship in the Chinese financial market ($SR \Rightarrow ER$, but $ER \nRightarrow SR$). Although the Shenzhen foreign stock market has been restricted from listing new foreign capital shares, the SZBI still has a significant impact on the return of RMB ordinary shares ($SR_{SZBI} \Rightarrow SR_{Shanghai}$) and the HSI ($SR_{SZBI} \Rightarrow SR_{HSI}$), as well as the exchange rate of HKD/RMB ($SR_{SZBI} \Rightarrow ER_{HKD/RMB}$). Since the return of Hong Kong, the Hong Kong stock market is closely related to mainland stock markets, but the fluctuation in the Hong Kong stock market shows no sign of effects on HKD/RMB. The change in the USD/RMB causes the variation in the HKD/RMB since the Hong Kong authorities adopts a linked exchange rate system (linked to the USD).

As the multivariate VAR model does not test the temporal effect between those markets, therefore, the conventional SVAR approach is carried out to investigate structural innovations between exchange rate changes and stock returns by imposing short run restrictions on the variance-covariance matrix (equation (3.11)), which is based on theoretical assumptions. The overidentfication test partially accepts the null hypothesis that the overidentifying restriction is still valid in this chapter. Due to some inefficiencies of the SVAR model, such as the normal assumption on model residuals and the counterintuitive assumption on short run parameters, Chapter 3 introduces the MS-SVAR model which allows coefficients and variances to be state-dependent to capture spillover effects between exchange rate changes and stock returns. The MS-SVAR model used in this chapter is a Bayesian form (Sims et al., 2008). The whole sample test indicates that three states with variances-switching is the best model. While other two subsamples (the samples for the 1997 Asian financial crisis and the 2008 world financial crisis) prefer two states with coefficients-switching and three states with variance-switching, respectively. The smoothed state probabilities in Figures 3.5-3.7 demonstrate that the MS-SVAR model captures the volatile structure of the Chinese financial market. High and low volatilities depicted in these figures represent tough and tranquil periods of the Chinese economy, which are generally consistent with the historical trends of the Chinese economy in the past two decades. High volatilities (tough periods) appear around mid-1997 and late 2007, but several tranquil periods are captured during mid-2001 and late 2006 (see Figure 3.6). After the 2008 global financial crisis, distressed periods are captured in mid-2010 and the second quarter of 2011, but the Chinese financial market shows good performance from late 2008 to mid-2010. Moreover, impulse response functions from MS-SVAR estimates indicate the parameter uncertainty of the identified spillovers between stock markets and foreign exchange markets. The shocks from the SHBI have positive influences on stock returns but a negative impact on exchange rate changes (see Figures 3.8-3.10). Other shocks are ambiguous due to the high parameter uncertainty cross the zero line. Added to that, spillover effects between exchange rate changes and stock returns have longer durations during the two post-crisis periods.

The final empirical chapter (Chapter 4) gives the analysis on the exchange rate exposure of Chinese firms at the industry and firm level. At the industry level, the Dynamic conditional correlation multivariate GARCH (DCC MGARCH) model takes into consideration the time-varying heteroskedasticity of the financial time series data, which is an analysis on the exchange rate exposure of Chinese firms at the macro perspective. Three different theoretical models for measuring exchange rate exposure have been separately investigated in this chapter, among which the market model and the three-factor model are appropriate for measuring exposures. The results from the DCC MGARCH estimates indicate that industry returns are mainly exposed to the changes in the RER and the TWEER. In estimating the exposure to RER changes, the average exposure coefficients estimated from the market model and the three-factor model are 0.019 and 0.093, respectively. Whereas the average exposure betas from the test of the TWEER changes are -0.195 (for the market model) and -0.346 (for the three-factor model), respectively. Among those estimated industry exposures, more than 37% of industry returns are significantly exposed to the change in the TWEER, and among which manufacturing industries are more likely to suffer from exchange rate changes. Further, the inclusion of lagged exchange rate variables in the theoretical model improves the convergence of the DCC MGARCH model, which effectively helps capture lagged exposure effects (Williamson, 2001; Doukas et al., 2003). In addition to the empirical results, the practical implication for selecting econometric methods is that the DCC MGARCH approach has found to be more effective in estimating exchange rate exposure when ARCH effects exist in error terms of the linear regression test.

For the firm level exposure, Chapter 4 introduces the SUR model to estimate exposures of firm returns using the cash flow approach at the micro level. The results from the SUR estimates vary across markets, but the evidence from the aggregate Chinese stock market indicates the existence of correlation between firm size and exposure effects when the TWEER variable is included in the model. This is consistent with the existing literature (Jorion, 1990; Dominguez and Tesar, 2006; Huffman et al., 2010). Moreover, the lagged exchange rate variable has also been found to be statistically significant at the firm level. This could be the reason that any spillover effects to the Chinese financial market could be contemporaneously restrained due to the restriction on the currency daily trading band. However, as the shock continues, lagged exchange rate changes have a significant impact on firm returns.

5.3 Policy Implications

This thesis aims to give an insight into RMB exchange rate dynamics and risks, which is based on empirical investigation of the Chinese economy and the Chinese financial market at the macro level, as well as the micro-level exchange rate exposure of Chinese exporting firms. From trade partners' points of view, China's growth must be related to its currency policy. This puzzle has been one of the motivations of this thesis. Basically, this thesis not only uncovers the question of China's growth and the nexus between RER and China's growth, but also has an in-depth analysis on the dynamics and risks of the RMB exchange rate.

Speaking from the policy perspective, the study on the long run equilibrium and short run dynamic between RER and economic growth in China has several important implications (see Chapter 2). Since trade partners believe that the managed floating exchange rate system has benefited China's exports but their products lost comparative advantages when they trade with China. Besides, investors are concerning about the causal relationship between the RMB exchange rate and the Chinese economy, since they are worried about potential risks from RMB policy changes. The first empirical chapter gives possible solutions. On the one hand, the results from the chapter have important implications for trade partners and investors. The findings indicate that China's growth is indeed an export-driven growth, but the RMB policy reform only had limited influences on the Chinese economy (in the short run). If trade partners adjust their own currency policies or continuously press the Chinese authorities to appreciate the RMB, it might not be very effective for reversing the situation of their trade deficits, since the labour-intensive products of Chinese firms are increasingly occupying the global market with the ongoing openness of China. The Chinese government will not give up the managed floating exchange rate policy in a short period. As revealed by the cointegration relationship, the RER is not singly determined by China's growth, therefore the intention of pressing the Chinese government to appreciate the RMB could be unpractical. Furthermore, since there are no structure changes evident from the 2005 RMB policy reform, any policies for adjusting investments or foreign trade strategies by referring to the breakpoint of the RMB policy change may be inappropriate, particularly in the long run. In addition to the long run policy implication, the great recession test indicates that the RMB exchange rate comparatively becomes more stable and flexible than before, which also suggests that the Chinese currency is largely relied on its comprehensive strength, rather than the slow increase in foreign trade. Thus, the intention of influencing the Chinese currency through speculation or pressing the Chinese government to appreciate the RMB might be unhelpful, since China owns a large amount of FER which could be used to adjust the uncertainties in foreign exchange markets. The direct experience in dealing with crisis (the experiences from the 1997 Asian financial crisis and the 2008 global financial crisis) also helps the authorities to cope with market uncertainties. Furthermore, the findings from the short run dynamics between RER and economic growth suggest that the speed of adjustment to previous equilibrium relationship is very slow. If investors pay much attention to long run exchange rate returns but ignore the short run correlation between RER and its determinants, investment returns might be affected. This is further discussed in the second empirical chapter.

On the other hand, the findings from Chapter 2 also have important implications for the Chinese authorities. In the long run, the equilibrium RER is determined by foreign trade, FDI and FER, but exports and FDI have the largest influence. This suggests that China needs to balance its foreign trade and inflow of foreign capital. When there is a long term depreciation in the Chinese currency, the authorities might make full use of the large amount of FER to restore the equilibrium of the RMB exchange rate. In the past three decades, the increase in exports mainly lies in the labour-intensive products. If the government wants to keep the long term export-driven growth, structural reforms are needed to be implemented in exporting industries, for instance, the investment in high-tech industries and services industries, or exporting to other new markets. In addition to the export-driven growth, the Chinese authorities might shift parts of growth strategies into domestic investment, such as investing in second-tier and third-tier cities. Concerning the Chinese currency policy, it is impossible that the Chinese government gives up the managed floating exchange rate system in a short time, since the sudden change to its currency policy might be detrimental to its growth, even the regional economy. In response to the continuous pressure from trade partners, the authorities might insist on the ongoing managed floating exchange rate policy making limited adjustments to the currency's daily floating range.

The results from Chapter 3 reveal the interactions between exchange rate changes and stock returns in the Chinese financial market. The findings have several points of implications for investors. The multivariate Granger causality analysis indicates that stock returns cannot Granger-cause exchange rate changes. If investors are actively speculating in the foreign exchange market of USD/RMB or HKD/RMB, there is no swift action needed to change their investment strategies when a shock happens in the RMB ordinary share market. However, investors have to make appropriate and prompt adjustments to their investments once there is a shock from the foreign capital share market, particularly the change in the SHBI, since the SHBI shock has a significant impact on other stock markets and foreign exchange markets. The shock from the SZBI is comparatively weak but it can still affect the Shanghai stock market and the foreign exchange rate of HKD/RBM to a certain degree. Further, the findings suggest that changes in exchange rates do not exhibit any significant spillovers to stock markets due to the implementation of a managed floating exchange rate system. Therefore, investors who are investing in the mainland China stock market do not have to worry too much about the fluctuation in the foreign exchange rate, especially in the short run. For the professionals (from investment companies or fund companies), as the conventional SVAR model cannot fully capture structure innovations in the Chinese financial market, they should refer to the results from the MS-SVAR estimates to adjust their portfolios. The MS-SVAR model with different regime-switching captures the volatile structure of the Chinese economy. Those professionals can easily predict the price change in the market according to the historical market statistics. Moreover, impulse response functions show that the SHBI shock has positive effects on stock markets but a negative impact on foreign exchange markets. While the shocks from other stock indexes are ambiguous due to the existence of parameter uncertainty. This means that investors should not solely refer to the fluctuation in the SHBI since the financial market is full of uncertainties. If the Chinese authorities have to respond to the pressure from trade partners by appreciating the RMB and making some changes to the currency policy, it may bring systematic risks to the Chinese financial market, which is what the investors and professionals are really concerned about.

The last empirical chapter should be of interest to investors, firm managers and policy-makers. The findings from Chapter 4 give the investigation of exchange rate exposure at both the industry and firm levels. For investors, the industry level exposure analysis have details about the effect of exchange rate changes on industry returns at the macro level, while the firm level exposure analysis gives the exchange rate exposure analysis at the micro level. Investors may take both aspects into account when they decide the indirection of their investments. The findings from the industry exposure analysis suggest that investors should consider more about their investments in manufacturing industries, since manufacturing industries are more likely to be exposed to exchange rate changes. As revealed by the industry level exposure finding, the change in the NER has less impact on stock markets compared with the changes in the RER and the TWEER. The average exposure beta for industry returns responding to the TWEER changes is -2.308 (see Table 4.14). Investors need to make appropriate adjustments when there is a shock in the TWEER. Additionally, results from the firm level exposure analysis suggest that investors should pay attention to the exchange rate exposure of large firms, as large firms are usually subject to more exposure effects. Although the managed floating exchange rate policy could protect the Chinese stock market from external shocks in the short run, but if the shock from the foreign exchange market continues, investors may consider withdrawing from the Chinese stock markets since lagged exchange rate changes are found to have significant exposure effects on industry and firm returns. For firm managers, they might consider to establish special commissions to hedge currency risks of their future cash flows, particularly for non-financial firms. The hedging strategy should not only focus on the USD since the TWEER has the largest influence on firm returns. For policy-makers, the changes in the RER and TWEER are expected to be controlled within a reasonable range in order to avoid severe spillovers from foreign exchange markets on the Chinese stock market. The authorities could make appropriate changes to exports structure in order to reduce the exchange rate exposure by combining the usage of FER and the adjustment of the managed floating exchange rate regime. This kind of currency policy may not be preferred by trade partners, but it is a vital tool for maintaining the local and regional economic stability. With the maturity of the Chinese financial system, the authorities could gradually loosen the restriction on the RMB exchange rate and further allow the RMB to be more flexible and tradeable in the foreign exchange market.

5.4 Areas for Future Research

This thesis investigates dynamics and risks of the RMB exchange rate. The findings of this thesis are of great importance to policy-makers, academic researchers and investors. Concerning the weakness of this research, there might exist some limitations due to the unavailability of some datasets, for instance, the monthly investment data before 1994 and the quarterly operating incomes of many Chinese listed firms. However, this thesis carries out the investigation based on carefully-selected variables and available datasets, all of the empirical modelling procedures and results are replicable. This might improve the reliability and accuracy of this study. Looking ahead, several interesting areas for future work could be undertaken.

In addition to the nexus between RER and economic growth in China, future topics associated with the RMB exchange rate could be the impact of RER misalignment on other macroeconomic sectors, such as exports, FDI, domestic prices and consumption. With the gradual loosening of restrictions on the RMB exchange rate policy, the research into RER misalignment can help to monitor its influences (and the historical effect) on the Chinese economy. Further, it might contribute to policy implications for reforming the Chinese currency policy. With regard to spillover effects between exchange rate changes and stock returns in the Chinese financial market, next action could be the change of endogenous variables (remove the HSI and HKD/RMB), data frequency (monthly or quarterly) and econometric methods (MGARCH models) to get more comprehensive and robust estimates, since financial markets are full of uncertainties and different variables with different data frequency and methods might generate interesting results. In terms of the exchange rate exposure of Chinese firms, future studies on this topic could be carried out with a small sample but high data frequency (daily data) at the industry level. Other extensions on the RMB exchange rate studies could be the internationalisation of the RMB and its connection with the global economy, particularly in financial sectors.

Other interesting topics related to these fields could be the examination of exchange rate exposure in other emerging economies, East Asian economies and the G20 economies. More straightforward studies are to carry out empirical analysis using existing research methods but different samples, such as the MS-SVAR and the MGARCH models. Furthermore, the innovative work might be the application of asymmetry models (both linear and nonlinear forms) into time series analysis, such as asymmetric spillover effects in financial markets and asymmetric exchange rate exposure. One avenue for further research could be the improvement of existing time series models, for instance, developing the nonlinear data generating process (regime-switching or nonlinear autoregressive distributed lag models) to restructure the Ng-perron unit root test. Finally, possible extension of personal research interests could be the application of panel data approaches into multinational samples, as well as the analysis on future reforms and influences of the RMB exchange rate using dynamic stochastic general equilibrium (DSGE) models.

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