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Exchange Rate Dynamics, Intervention and Regime Shifts in China: A Market Microstructure Analysis

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A thesis submitted in partial fulfilment of the requirements for the
degree of Doctor of Philosophy in Accounting and Finance

School of Economics, Finance and Business

University of Durham

2013

To My Grandmother, Parents and Husband

Abstract

This thesis applies the market microstructure approach to investigate exchange rate dynamics, intervention and regime shifts in China's exchange rate system. This research first examines exchange rate determination and dynamics from a microstructural perspective. An index of order flow is constructed in the Chinese context to reflect excess demand pressure. A VAR model is then estimated to explore to what extent order flow may explain long-term determination and short-term fluctuations of the renminbi exchange rate. Focusing on the cointegrating relationship between cumulative order flow and the exchange rate of the RMB against the US dollar, this research find that in the new Chinese exchange rate regime in place since 2005, order flow is able to explain a significant part of fluctuations in the RMB-dollar exchange rate.

China is internationally noted for its intervention in the foreign exchange market. Based on high-frequency data this thesis adopt a multi-dimensional approach to explore how interventions are conducted in China, what the consequences are, and to what extent they are effective. This thesis identify evidence of China's extensive intervention and find that the authority is more likely to intervene to curb devaluation. Decomposition analysis shows that the direct impact of intervention on the exchange rate is more important than the impact via order flow. Intervention via the central bank's involvement in trading is effective in influencing both the exchange rate and order flow, but tends to increase volatility. Intervention by the central bank's varying the central parity condition plays some role in 'leaning against the wind', but cannot reverse the trend.

China announced the reform of its exchange rate system in 2005. The reform was disrupted by the breakout of the global financial crisis around 2008, but was reiterated in 2010. The thesis analyses the behaviour of China's exchange rate policy since then. This research detect 21st June 2010 as the date of regime shift, since when the RMB has been allowed greater room for flexibility, and consequently exchange rate volatility has increased. This research unearths evidence confirming that the renminbi no longer pegs only to the dollar. During the crisis period, deviations from the central parity rate (CPR) increase the possibility of government intervention, and the intervention correlates with bid-ask exchange rate spread. The Chinese monetary authority is found to act to keep the exchange rate stable. In the post-crisis period, the correlation becomes time-varying and the government prefers the RMB exchange rate to gradually appreciate. This research finds evidence that appreciation of the RMB exchange rate is order flow driven during the post-crisis period.

There is a significant negative currency exposure during the financial crisis, caused by changes in the RMB exchange rate, indicating that the Chinese stock market exhibits a negative reaction in the period. However, no significant impact is found in the post-crisis period. In order to modify the exchange rate exposure to fluctuations of the US dollar, the Chinese government seems to have adopted the relatively more efficient exchange rate regime to handle the effects of the global financial crisis.

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My grandmother taught me to achieve honour through effort, attitude and hard work. In all my pursuits of my passions, including my academic dreams, Mom always believes in me and listens to my wishes and worries. Thank you, Dad, for so many things, and particularly for letting me climb to your shoulder to see the light of hope in life and for inspiring me to reach my potential. I love you all.

Declaration

The content of this doctoral dissertation is based on the research work completed at Durham University Business School, UK. No material contained in the thesis has previously been submitted for a degree in this or any other university.

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Chapter 1

Chapter 1 Introduction

In this chapter begin by introducing the background to the study. Next, this chapter set out the main motivations behind the research and the potential contributions of this thesis to the literature. Key research problems to be tackled and the main findings of the thesis are then presented. Finally, this chapter outline the organisation and structure of the entire thesis.

Chapter 1

Introduction

In recent decades, there has been much debate about China's exchange rate policy. Given the nation's rising importance in the world economy, and the growing complexity of economic and financial globalisation, it is desirable yet challenging to achieve a better understanding of how the value of China's currency (renminbi, or RMB) is determined in the long run, and to identify the dynamics of RMB movement in the short run. In order to comprehend these fundamental issues, this research must first discern the evolving role of the government in the foreign exchange market and in driving the regime changes in China's exchange rate system.

Studies of exchange rate issues are conventionally shaped by the macro approach, which focuses on interactions between macroeconomic factors and the exchange rate. However, there is growing recognition that the market microstructural approach can shed additional light on many critical aspects of the exchange rate. Hence, this research will examine factors that affect the RMB exchange rate and its regime shifts from a microstructural perspective.

1.1 Motivations and Contributions of this Research

Over the last few decades, the application of macroeconomic models to the study of exchange rates has met with growing challenges, because of the models' poor performance in capturing exchange rate movements (Meese and Rogoff 1983, Frankel

and Rose 1995). In response to the poor explanatory power exhibited by conventional macro models, the market microstructure approach has been widely used in analysis of exchange rate determination. O'Hara (1995, p. 1) defines the market microstructure approach as one that studies 'the process and outcomes of exchanging assets under explicit trading rules'. In recent studies of exchange rate economics, trading has been considered a central element in the process of price formation. In turn, the trading process is centred around order flow; hence order flow becomes the focal point of the microstructure approach. By testing for its capability to transmit information on price formation, recent empirical work has confirmed the explanatory power of order flow (Evans and Lyons 2002b).

However, existing research has been primarily concerned with mature economies and with the world's major currency pairs. Very few studies have investigated the potential role of order flow in foreign exchange markets of emerging economies. This research represents one of the first attempts to fill the gap in this field by applying the microstructure approach to China. Specifically, this research is motivated by the desire to shed light on the exchange rate determination and dynamics in China from a market microstructure perspective.

In doing so, this study intends to make several potential contributions to the literature. First, this study is among the first to apply the market microstructural approach to the Chinese foreign exchange market. The market microstructural approach can supply more minutiae and can examine more closely the working of the Chinese foreign exchange market. A small number of studies have applied this approach to the case of China, but existing research fails to supply sufficiently detailed empirical analysis. This thesis fills towards that gap by applying the market microstructure approach with

high-frequency transaction data. The thesis constructs a measurement of order flow that is based on all tick-by-tick transaction data from the CFETS (China Foreign Exchange Trading System), from which the cumulative daily order flow is computed. The research also takes into consideration the trading system reform and the consequent market evolution. The sample spans the periods before and after 21st June 2010 when the government re-launched a new ‘managed floating’ exchange rate system.

This thesis is also motivated to research into intervention in the foreign exchange market, a feature for which China is noted internationally. Intervention is widely used as a powerful tool for central banks to control the level and change of their currencies. Given China’s growing economic power and the possible repercussions of its intervention, this thesis is interested to establish how China’s monetary governance manages the exchange value of renminbi and whether this management, or intervention, is effective.

The second major contribution that this investigation intends to make is related to the Chinese intervention in the foreign exchange market, a feature for which China is noted internationally. Intervention is widely used as a powerful tool for central banks to control the level and change of their currencies. Given China’s growing economic power and the possible repercussions of its intervention, we are interested to establish how China’s monetary governance manages the exchange value of renminbi and whether this management, or intervention, is effective. The potential contributions of our investigation in this area include the follow aspects. Like many other governments, the Chinese monetary authority has wrapped its intervention in secrecy. Using a wide range of sources, this study identifies the dates and establishes the main types of the

secret intervention. The research gathers the newswire reports about intervention from one of the world's biggest news databases, Factiva; it also uses Reuters China, and the SAFE (State Administration of Foreign Exchange) official website to estimate the Chinese monetary authority's intervention action. The target data set of this research includes the major part of year 2012. This is an eventful year, as it includes both the Sino-America currency dispute, a central issue in the current world economy, and the change of leadership in some major powers. Hence it provides a rich context for our study, which aims at a better understanding of how the Chinese monetary authority intervenes in the foreign exchange market, and the consequences thereof.

The third main motivation behind this study is to investigate what de facto regime has been operated in China. It is often the case that the exchange rate regime announced by a government differs from the one that operates in reality; in other words, the de jure regime could be fundamentally different from the de facto regime. This research intends to ascertain what de facto regime has been in operation in China since the regime shift announced by the Chinese monetary authority. As the regime shift happened to coincide with the periods during and just after the global financial crisis, the research also intends to look more deeply into the behaviours of the Chinese exchange rate regime across the global financial crisis.

Thirdly, the research makes an important contribution to the literature regarding the regime shifts in China's exchange rate system. It is often the case that the exchange rate regime announced by a government differs from the one that operates in reality; in other words, the de jure regime could be fundamentally different from the de facto regime. This research intends to ascertain what de facto regime has been in operation in China since the reform announced by the Chinese monetary authority. As the

regime change happened to coincide with the periods during and just after the global financial crisis, the research also looks deeply into the behaviors of the Chinese exchange rate regime across the crisis. In this regard, the contributions of this thesis to the literature can be categorized in terms of detection of the regime changes and its consequences. In order to detect the exact timing of exchange rate regime shifts and the currency weights in the reference basket of currencies, this research adopts two different regime shift models. One model is based on the variance frequency, i.e., low variance or high variance. The other is based on the currency weights. If the weights of reference basket currencies change we can define this as a regime shift. This thesis uses high-frequency transaction data from across the global financial crisis period. The data set covers the period from 22nd July 2005 when the Chinese government announced adoption of a managed floating RMB exchange rate regime, until 9th October 2012. By applying the multiple GARCH model we are able to find the impact of China's exchange rate regime shift during the financial crisis and post-crisis periods from various perspectives.

1.2 Research Questions and Main Findings

This thesis aims to improve our understanding of the Chinese exchange rate policy from a market microstructural perspective. To accomplish this aim, this research investigate the determination of the RMB exchange rate and its dynamics, the intervention in the foreign exchange market and its effectiveness, and the recent regime shifts in China's exchange rate system, which are intertwined with the fallout of the global financial crisis. Using various techniques of the market microstructure approach, this research attempt to solve the following research problems:

1. In the price formation process, to what extent can order flow analysis explain the long-term determination of the exchange value of the Chinese renminbi, or RMB, against other international currencies, particularly the US dollar?
2. In a system with the variable space containing the exchange rate, order flow, international interest differential and risk premium, how do interactions between these variables determine the dynamics of the system and the short-run dynamics of the Chinese exchange rate?
3. In what ways does the Chinese monetary authority intervene in the foreign exchange market? Does intervention have a significant impact on exchange rate returns and order flow?
4. What is the relative importance of different forms of intervention? How can we judge the extent to which Chinese intervention is successful? What are the costs?
5. Given the possibility that the de jure system can be quite different from the de facto one, it is natural to ask whether China's recently announced adoption of a new exchange rate regime represents a true regime break. If not, has there been a regime change subsequently, and if so, when?
6. What are the consequences of the regime break in China? In particular, are there changes in the policy course after the detected date of regime switching in terms of the speed of exchange rate changes and the degree of flexibility of the exchange rate system?

In order to explore these issues, this research first constructs a measure of order flow based on high frequency transaction data from the Chinese market, and computes the daily order flow. Then, this research add a control variable, the country risk premium, which prior studies have shown to have explanatory power with regard to exchange rate dynamics in emerging markets. Focusing on the cointegrating relationship between cumulative order flow and the exchange rate of the RMB against the US dollar, this thesis find that in the new Chinese exchange rate regime in place since 2005, order flow is able to explain a significant part of fluctuations in the RMB-dollar exchange rate.

Based on high-frequency data this research adopt a multi-dimensional approach to explore how interventions are conducted in China, what the consequences are, and to what extent they are effective. This work identify evidence of China's extensive intervention and find that the authority is more likely to intervene to curb devaluation. Decomposition analysis shows that the direct impact of intervention on the exchange rate is more important than the impact via order flow. Intervention via the central bank's involvement in trading is effective in influencing both the exchange rate and order flow but tends to increase volatility. Intervention by the central bank's varying the central parity condition plays some role in 'leaning against the wind', but cannot reverse the trend.

In order to detect the exact timing of the China foreign exchange rate regime change, this research adopt two contrasting methods, as introduced by Engel and Hamilton (Engel and Hamilton 1990) and by Zeileis et al. (2010). One of the regime shift models is based on the variance frequency, i.e., low variance or high variance. The other is based on the currency weights. If the weights of currencies in the reference

basket have changed it is then defined as a regime shift. Both methods identify 21st June 2010 as the regime shift date.

Next, this research use the multiple GARCH model to examine the impact of exchange rate regime shift during the financial crisis (before 21st June 2010) and post-crisis (after 21st June 2010) periods from various perspectives. This research find that since the date of regime shift the RMB has been allowed greater room for flexibility, and consequently exchange rate volatility has increased.

The thesis unearths evidence confirming that the renminbi no longer pegs only to the dollar. During the crisis period, deviations from the central parity rate (CPR) increase the possibility of government intervention, and the intervention correlates with bid-ask exchange rate spread. The Chinese monetary authority is found to act to keep the exchange rate stable. In the post-crisis period, the correlation becomes time-varying and the government prefers the RMB exchange rate to gradually appreciate. This research finds evidence that appreciation of the RMB exchange rate is order flow driven during the post-crisis period.

1.3 Organisation of the Study

This thesis comprises seven chapters. The structure of the thesis is as follows:

- **Chapter 2: Review of Related Literature.** In this chapter, this research reviews the literature of the microstructure approach and the comprehensive surveys and critical assessments relevant to the research in this thesis.

- **Chapter 3: Microstructure of the China FX Market.** In Chapter 3, this research gives a general introduction to the background of the China foreign exchange market under the microstructural perspective.
- **Chapter 4: Exchange Rate Determination and Dynamics.** In this chapter, this research investigates the relationship between order flow and exchange rate in the China FX market within the market microstructure framework. This chapter aims to shed some light on exchange rate determination in China.
- **Chapter 5: Chinese FX Intervention.** Chapter 5 proposes the multiple perspectives framework to analyse the action of exchange rate and order flow when the Chinese government intervenes in the foreign exchange market.
- **Chapter 6: Exchange Rate Regime Shift.** In Chapter 6, this research examines the different performance of the China exchange rate regime across the global financial crisis. This chapter aims to detect the exchange rate regime changes, in order to better understand the central bank de facto operations.
- **Chapter 7: Conclusions.** In this final chapter this thesis summarise the results of this work. Then, this chapter give suggestions for future research.

Chapter 2

Chapter 2 Literature Review

This chapter reviews the comprehensive surveys and critical assessments relevant to the work in this thesis. First, this chapter give a brief overview of the related literature of the microstructure approach. Then, this chapter review the related literature of foreign exchange intervention. Finally, this chapter present a detailed survey of the studies on exchange rate regime shifts.

Chapter 2

Literature Review

2.1 Related Literature of Market Microstructure

The first section briefly reviews previous literature on the microstructure approach to exchange rate dynamics. The microstructure approach underscores the central role of the trading process in the price formation in the foreign exchange market (Lyons 1995). This process can be broadly grouped into three phases (Evans 2011). First, the customers trade with their personal dealers. Then, these dealers carry their own customer orders to trade with other dealers through the electronic interdealer market; the transactions in this market are known as interdealer trades. In the last round, dealers trade with customers again to balance their net inventory position.

In this process, the trading size and transaction position are the most important factors for these transactions. These critical parameters of the market are summarized by order flow, which is the net balance of buyer-initiated and seller-initiated foreign exchange market transactions (Lyons 2001). Measured as the sum of the signed seller-initiated and buyer-initiated orders in the empirical specification, order flow is considered an important information transmission mechanism linking price changes and dispersed information. Indeed, the explanatory role of order flow in exchange rate models has been the focal point of empirical studies in the market microstructure literature, which can be generally catalogued in terms of those using data of customer

order flow and those using interdealer order flow. However, the majority of empirical research focuses primarily on the customer order flow as it conveys private information about not only fundamentals but also monetary policy (Evans and Lyons 2006, Bjørnes and Rime 2005, Rime 2000).

Nevertheless, because of the availability of data, many studies have focused on the data of interdealer order flow from the electronic transaction market. For example, Danielsson et al. (2012) investigate 10-month order flow data from the Reuters D2000-2 data platform and find that order flow Granger causes the changes in exchange rate returns. Influential research by Evans and Lyons (2002b) use the interdealer order flow based on the 4-month data of the exchange rates between the deutschemark and the Japanese yen against the US dollar from Reuters D2000-1. In a radical departure from the conventional macro models, the authors develop a hybrid model that contains both a macro variable (interest differential) and a micro variable (order flow). They find that over 60% of the USD/DEM daily changes and 40% of the USD/JPY daily changes can be explained by order flow. In another study, Evans and Lyons (2002a) extend their dataset to seven currency pairs: the US dollar against the pound sterling, Belgian, French and Swiss francs, Swedish krona, Italian lira and Dutch guilder. They find that order flow may generate an R^2 up to 78% on a daily frequency. However, Fisher and Hillman (2003) extend the research of Evans and Lyons (2002a) but get much lower R^2 statistics results. Berger et al. (2008) show that interdealer order flow has a 0.65 correlation with the exchange rate of the EUR/USD.

Osler (2006) summarize three explanations of order flow driving exchange rate movements: the inventory effect, information effect, and downward-sloping demand and liquidity effects. The inventory effect refers to the situation whereby any

deviation from the desired inventory level will expose dealers to risk. To avoid undesired risk, dealers will decrease (increase) their prices to attract more buying (selling) orders when their inventory positions are higher (lower) than desired levels.

Inventory-based models can successfully explain the temporary changes in the exchange rate but fail to capture permanent exchange rate movements. Information-based models imply that order flow should permanently affect market prices. Hence, exchange rates should be cointegrated with cumulative order flow. Recent research has uncovered evidence for such a stable long-term relationship for several currency pairs (Killeen, Lyons, and Moore 2006, Bjørnes and Rime 2005). However, Boyer and Van Norden (2006) point out that these results are selective and, in some cases, the results are statistically weak and suffer from a small sample bias. They conduct cointegration tests on the dataset of Evans and Lyons (2002b), which is commonly used in other research. Strikingly, they find no evidence of a long-run relationship between order flow and the exchange rate. Osler (2006) also introduce ‘downward-sloping demand and liquidity effects’ to explain why order flow is important. He suggests where there is long-term downward-sloping demand with a growth in supply, price will decrease in the long run. If there are no changes in the fundamentals, then one country’s currency demand is equal to the other country’s currency supply. Rime et al. (2010), however, argue that order flow of other currencies should be included in the model specification, as they can greatly increase the explanatory power of interdealer order flow.

In an early study of the New York Stock Exchange, Hasbrouck (1991) propose a simple linear VAR model for the microstructure study. Payne (2003) apply this modeling strategy to analyze the foreign exchange market. He draws on the 1-week

exchange rate of USD/DEM from Reuters D2000-2, covering the time period from 6 October to 10 October 1997. The results show that 60% of the variation can be explained by the private information, suggesting that informed order flow has explanatory power for exchange returns. Froot and Ramadorai (2005a) also set up a VAR model to test order flow as a major medium of fundamentals and exchange rate movements. They divide the exchange rate returns into permanent and transitory shocks and study the interactions between them. They illustrate that order flow is related to short-term currency returns but that fundamentals better explain long-term returns and values. These findings highlight the importance of research on the role of order flow in short-term dynamics and long-term determination of the exchange rate.

However, the extant literature has focused on the major currencies. For example, Ito et al. (1998) investigate the JPY/USD and find that the informed order flow can predict the exchange rate over the short time period. Rime (2000) examines five major currencies against the US dollar, DEM/USD, GBP/USD, CHF/USD CAD/USD and JPY/USD, from July 1995 to September 1999. The results of cointegration tests show that the exchange rates of DEM/USD, GBP/USD and CHF/USD have a cointegrating relationship with order flow, indicating that the lagged order flow has an explanatory power of exchange rate movements. Researchers have also explored the explanatory power of order flow for many other major currencies, including the euro (Evans and Lyons 2005), the deutschmark (Andersen et al. 2002), and the British pound (Berger et al. 2008).

In recent decades, a growing number of studies have analyzed the explanatory power of order flow in emerging markets. Galati (2000) study the currencies of seven emerging markets—Colombia, Mexico, Brazil, India, Indonesia, Israel and South

Africa—with 18-month daily trading volume data and finds that most trading volumes are significantly and positively correlated with volatility. Froot and Ramadorai (2005a) examine 19 countries with more than four years' daily data and include 111 rates in their international portfolio flows. They find that these flows are strongly significant and positively correlated with contemporaneous exchange rate returns.

Frankel (2010) survey the monetary policies of emerging markets and notes that many researchers have designed their models to take into account the unique features of emerging markets, such as imperfect institutions, moral hazard, default risk and illiquidity, asymmetric information, and government intervention. De Medeiros (2004) consider Brazil's foreign exchange market and introduces the country risk premium as an additional control variable. He finds that Brazil's order flow data have a weak performance compared with those in developed countries but that the country risk premium is more significant than other variables. Wu (2012) also add a risk premium as the control factor in his model. He examines both the temporary and permanent period behaviors of commercial and financial customer order flow in the Brazilian foreign exchange market with four years' daily customer transaction data. His results show that financial and intervention flows are positively related with exchange rate movements but that commercial flows are negatively associated with the exchange rate and have feedback effects.

Many other special conditions of emerging market figure prominently in such research. Gereben et al. (2006), for instance, explore the role of domestic and foreign customer flow in the Hungarian foreign exchange market and find that liquidity is largely determined by domestic customer flow while the information of foreign customer flows drives the fluctuations. Galac et al. (2006) study the role of market

microstructures in explaining the relationship between trading volume, volatility and bid-ask spreads in Croatia. Ranjan et al. (2008) focus on the exchange rate movements of the Indian foreign exchange market. Duffuor et al. (2012) examine the role of end-user customer order flow in explaining the exchange rate changes in the Ghanaian market. They use the black and official market exchange rates to investigate the roles of expected and unexpected order flows and find that expected order flow has inefficient performance in the foreign exchange market.¹

Motivated by these empirical studies and findings, this research seek to determine in this thesis the extent to which order flow explains the behavior of the exchange rate of an emerging market currency against an international key currency, i.e., the exchange rate of RMB against the US dollar. To facilitate such an investigation, it is important to briefly outline the microstructure of the Chinese foreign exchange market centered on the China Foreign Exchange Trading System (CFETS) so as to establish the background knowledge for this system, which is essential for understanding China's exchange rate movements from the market microstructure perspective (Zhang, Chau, and Zhang 2012).

2.2 Related Literature of Foreign Exchange Intervention

In this section this research review the related literature, focusing particularly on the intervention studies that take a microstructure perspective. The disintegration of the Bretton Woods system in the 1970s was a catalyst for large-scale exchange rate

¹ Outside the extant market-microstructure literature, Vygodina et al. (2008) documents that exchange rates overreact to changes in economic fundamentals over the short run but converge in a long run. Using an event-study methodology and the exchange rates of three MENA countries i.e., Egypt, Morocco and Turkey, Chortareas et al. (2012) shows that devaluation announcement caused excess volatility in these markets.

intervention. Subsequent to the interventions by the central banks of the Group of Five (G5), which engaged in joint interventions for nearly ten years until the end of the 1980s, many countries followed suit to use intervention as a useful instrument to stabilize their currencies. From the 1980s in particular, central bank interventions became an increasingly popular research area, with most economists seeing intervention as both costly and ineffective (Edison 1993). The focal point at the time was sterilized intervention, and the main concern was whether intervention could significantly affect the exchange rate. Mussa (1981) proposed the ‘signalling hypothesis’, and demonstrated that the future signal would affect exchange rate changes. While Dominguez and Frankel (1993) confirmed the existence of such an effect, most other researchers remained sceptical. For example Vitale (1999) argued that central banks would be reluctant to reveal their interventions, since their objectives might not be in alignment with what the fundamentals would suggest. In his view, secret interventions would send ‘wrong signals’ to the FX market. Rogers and Siklos (2003) summarized that central bank intervention produces portfolio effects and signalling effects to influence the exchange rate. By indirectly affecting the returns on foreign assets through exchange rate movements the central bank intervention causes portfolio effects whereby investors adjust their portfolios. In addition, the government intervention will convey policy information to the market, hence producing signalling effects inducing investors to adjust their expectations of future exchange rate returns.

High-frequency data analysis has proved useful to identify, and provides a more accurate understanding of, central bank intervention, since high-frequency data are more comprehensive and precise (Menkhoff 2010). Vitale (2007) summarizes the microstructure literature on central bank intervention and, using a microstructure

model, suggests that secret interventions could impact exchange rate changes. Among the many researchers to have conducted microstructural studies, Goodhart and Hesse (1993) use Reuters headline news as high-frequency information. They establish the conditions for intervention, but no clear evidence of price impact. Dominguez (2003) applies an event study, and finds that interventions can significantly influence exchange returns of two major currencies (JPY/USD and DEM/USD). She also sets the data time to compare 2 hours before and after intervention and finds that intervention days have higher volatility. Chari (2007) follows Dominguez's (2003) method to test the intervention responses of 125 banks and finds that following intervention the bid-ask spread normally increases and that top banks have different quotes reactions to intervention.

Based on high-frequency news data, the literature is also able to distinguish actual intervention from reported intervention, and hence to establish the accuracy of news reports about intervention. Klein (1993) compares the Federal Reserve published daily data of actual intervention with the related press reports by the *Wall Street Journal* and the *New York Times*. He finds that the press reported only 72% of actual interventions, and of the reported interventions only 88% actually occurred. Fischer (2006) compares the data of the Swiss National Bank for four major currencies with Reuters news reports, and finds that all reported interventions did happen and nearly 90% of actual interventions were reported. However, the Reuters news reports came after the actual interventions and the gap could often be measured in hours rather than minutes. In contrast, Galati et al. (2005) find that Reuters news reports are precise and accurate to catch the Japanese foreign exchange interventions.

Different countries have different intervention actions, according to their specific exchange rate regimes. For example, under a floating exchange rate a governing authority will occasionally intervene in the foreign exchange market. However, in the case where a particular country has ambitious stabilization objectives, the government will intervene frequently. Payne and Vitale (2003) use tick-by-tick transaction data with an event study approach to analyse intervention by the Swiss National Bank. They apply Hasbrouck's (1991) structural VAR approach to analyse the price impact in terms of two distinct aspects: information effects and liquidity effects. Pasquariello (2010) expands the previous Swiss data set to 1998 and uses 5-minute interval quotes. He finds that interventions are significant in affecting market volatility and spreads, and the effects are persistent. Like the Swiss National Bank, the Bank of Canada also provides its intervention data to the public. Fatum and King (2005) analyse the behaviour of the Canadian dollar against the US dollar, and find that intervention can reduce exchange rate volatility but is ineffective in controlling currency co-movements. With regard to the impact on market behaviour, the Japanese central bank always intervenes around the lunchtime in the Tokyo time zone.

Kim (2007) sets two intervention time periods of 24 hours, both starting overnight but with one ending at the London closing time and the other during the New York afternoon hours. He finds that the first horizon intervention has unwanted results, but the second horizon intervention impacts returns immediately and reduces the volatility effectively. Fatum and Pedersen (2009) use intervention information from the Danish central bank and demonstrate that interventions significantly influence exchange rate returns. They also show that intervention, as a short-term instrument and without previous announcement, cannot affect the exchange rate immediately.

Overall, use of high-frequency data in intervention analysis has performed better, and achieved more effective and significant results. Most studies provide strong evidence that intervention can move the exchange rate in the required direction in the short term and effectively reduce volatility. Recent research has used even higher frequency data to analyse central bank intervention. This has proved to be more precise and helpful to direct policy-makers, and could be instrumental for analysing China's intervention in the foreign exchange market.

For emerging markets, the lack of sufficiently high-frequency data before the late 1990s obstructed the development of the intervention literature. The two major electronic trading platforms and data vendors, EBS and Reuters, now provide detailed and global-scale high-frequency data on major currency pairs, which facilitates the microstructure study in the field (Berger et al. 2008). The microstructure approach is now widely applied.

Evans and Lyons (2003) bond intervention and order flow together. They show that interventions contain current/future FX policy information, which is conveyed by order flow to impact the price. They highlight that the whole day trading process would reveal how order flow conveys information to affect the portfolio balance and transaction price. In their view, if the intervention trades are sterilized, secret, and provide no policy signal, the intervention will be effective. Vitale (2011) formulates a model to analyse market conditions for interventions and the impact of the interventions on exchange rate values from the microstructural perspective. In testing the model, he notes the importance of choosing the best route for intervention, because it not only changes the exchange rate, but also impacts on the market conditions.

Menkhoff (2013) points out that some emerging market interventions differ from those in advanced economies. Many emerging economies have under-developed institutions and less diversified economic environments, but they hold huge amounts of foreign reserves and actively seek the best ways to manage intervention for maintaining market stability. This has rekindled researchers' interest in looking for evidence on the effectiveness of interventions in these countries. Disyatat and Galati (2007) use daily information from 2001 to 2002 to study the effect of intervention in the Czech market. They find that intervention impact on the spot rate is slightly significant, but there is no direct effect on short-term volatility. Scalia (2008) uses daily and hourly information to analyse Czech intervention in the CZK/EUR rate during the period 1st July to 30th December 2012. He finds that order flow significantly affects the exchange rate. Scalia (2008) divides the Czech Republic intervention regime into three types. For totally secret intervention, the price impact on the exchange rate is 6.6 basis points per 10 million euro of order flow. This rises to 9.3 basis points for partially expected intervention, while for expected intervention it is nearly double, at 12.2 basis points per 10 million euro order flow.

With regard to Asia, Marsh (2011) examines the effectiveness of Japanese intervention during the period August 2002 to March 2006, covering 890 trading days. He notes that there is limited evidence of correlation between the customer and interventions, but on intervention days the customer prefers to be the net buyer. Marsh (2011) also indicates that the correlation between order flow and exchange rate disappears when the Bank of Japan intervenes.

Informed by the development of this literature, in particular the work within the microstructural approach using high frequency data, this chapter examines from a

microstructural perspective to what extent the Chinese intervention is effective. Emphasis is placed on the role of order flow in the process. In particular, this research explores how order flow transmits signals between intervention operations and the exchange rate via the information and liquidity effects.

2.3 Literature Review of Exchange Rate Regime Shifts

In Section three, this chapter review the relevant literature including those on the classification of exchange rate regimes, the methods of identifying the timing of regime shifts and the economic significance of currency risk exposure.

2.3.1 De Jure and De Facto Exchange Rate Regimes

Since the breakdown of the Bretton Woods system, exchange rate volatility has been a major topic in economics. In the more recent literature, the debate has centred in particular on de facto exchange rate arrangements. Klein and Shambaugh (2010) note that since 1950, what the International Monetary Fund (IMF) have presented in its annual report on members' exchange rate arrangements have been the de jure exchange rate regimes, which may differ from the actual regimes. Calvo and Reinhart (2002) state that although governments may announce the adoption of floating exchange rate regimes, in general they have a 'fear of floating'. As a result, the actual practice of central banks often differs from the stated exchange rate regime. For example, if a government is seeking to keep the exchange rate stable under a flexible exchange rate regime, it might intervene to limit the exchange rate volatility.

Alternatively, if a government is unable to maintain a reportedly fixed exchange rate regime, the exchange rate might exhibit variability. This gap between the government

announced (de jure) and the actual (de facto) operations has prompted many researchers to attempt to classify the de facto exchange rate regime (e.g., Levy-Yeyati and Sturzenegger, (2005) Reinhart and Rogoff, (2004) Eichengreen and Razo-Garcia, (2011). In one of the first studies to classify exchange rate regimes using an approach different than that of the IMF, Levy-Yeyati and Sturzenegger (2003) focus on the behaviour of macro-variables. They find that the slower economic growth and much greater output volatility in the developing countries are related to governments' use of less flexible exchange rate regimes. Reinhart and Rogoff (2004) develop a new classification of exchange rate regimes and find that the breakdown of the Bretton Woods system had less impact on changes to the regimes than suggested in previous studies. Shambaugh (2004) uses the real behaviour to classify exchange rate regimes, and finds that the fixed rate countries follow the base country's interest rate more closely than do countries where there is no peg. Benassy-Quere, Coeure and Mignon (2006) examine 139 countries with regard to their exchange rate pegging to basket currencies, and find that the hard peg regimes do not have any diminishing trend even after the financial crisis period.

The U.S. dollar is still the major fixed currency. Patnaik et al. (2011) argue that during the financial crisis 'fear of floating' caused Asian countries to reduce the flexibility of their exchange rate regimes, but after the crisis exchange rate flexibility became greater than in the prior period. Meanwhile, most of the Asian countries continue to reduce the role of the U.S. dollar and slowly increase the flexibility of their currencies. Aizenman and Sun (2012) maintain that in recent decades, the fear of floating has induced governments to hoard huge amounts of international reserves. However, during the global financial crisis, 'fear of losing international reserves' proved stronger than 'fear of floating'.

Some researchers have focused their attention on the de facto exchange rate regimes of emerging markets, especially China (Eichengreen 2007, Williamson 2000). Frankel and Wei (2007) assess the nature of China's exchange rate regime after the changes introduced by the government in July 2005. They find that after that announcement, the de facto regime of China is such that the RMB is still pegged to the dollar. Goldstein and Lardy (2008) summarise the debate on the advantages and disadvantages of China's exchange rate policy since July 2005. Frankel and Wei (2008) use a new approach with two techniques on 20 currencies to estimate the de facto exchange rate regimes in China over the period 1980 to 2007. Frankel (2009) examines the China foreign exchange regime based on currency weights in, and flexibility of, the reference basket. He finds that in mid-2007, the RMB exchange rate switched from a dollar peg to a peg mainly to the euro, but without additional currencies in the reference basket.

Fidrmuc (2010) applies the Kalman filter to investigate the weights of the unpublished reference basket currencies over the period 2005-2009. He finds that the U.S. dollar maintained a greater weight until the breakout of the recent global financial crisis around 2007. Frankel and Xie (2010) use two approaches to estimate the de facto weights of the reference basket and the de facto degree of exchange rate flexibility. They find that the real world data allows the regimes to change frequently. Meanwhile, Zeileis et al. (2010) employ a unified toolbox to estimate, among others, the exchange rate regime of China since July 2005. Zhang et al. (2011) develop a formal model to investigate the optimal weights of the basket currencies for China, which gives normative indications of the possible currency composition of the basket China uses as a central element of the new exchange rate regime.

2.3.2 Regime Shift Models and Exchange Rates

To capture the exact timing of the regime shift, this research must first find the structural break points. The conventional test for structural break points (Chow 1960) is conditional upon knowing the dates of the structural breaks. Andrews (1993) extends the Chow test to identify the structural breaks without knowing the break points in advance. Alternatively, Hamilton (1989) and Engel and Hamilton (1990) use a new and different approach to discern structural breaks, based on exchange rate dynamics.

In the literature, the Markov regime switching model has been widely used to characterise the behaviour of the real interest rate, for example in the work of Garcia and Perron (1989). Engel and Hamilton's (1990) pioneering work introduces an entirely new statistical model of exchange rate dynamics in two regimes. Engel (1994) shows that the Markov switching model can explain the dynamic changes of 18 currencies and finds the model to have better performance in predicting exchange rate changes.

However, applying the Markov switching model to daily exchange rate data, Marsh (2000) finds that this model has poor forecasting capability for out of sample exchange rates. Clarida et al. (2003) show better prediction of the out of sample exchange rates with the MS-VECM model (i.e. Markov switching vector error correction model).

Using the Markov regime switching model for three major exchange rates, Frömmel et al. (2005) reveal the relation between the underlying fundamentals (such as the real interest rate differential) and the exchange rate based on a microstructure approach.

However, they find the out of sample forecasting power of the Markov model to be poor. Dueker and Neely (2007) employ the Markov switching model to explore the trading rules to predict the trend of exchange rate returns. They find no evidence to prove that higher moments of the exchange rate can increase the returns. Yuan (2011) proposes a multi-state Markov switching model to model exchange rate trends with filtering techniques. The findings indicate that the model has significant forecast performance for both in sample and out of sample exchange rates. Khemiri (2012) uses the Markov switching model to explore the relation between exchange rates and the underlying fundamentals. In order to examine the exchange rate dynamics, he employs the Markov switching model to take the exchange rate volatility and the regime switching into consideration. He finds that a positive relation between the volatility and volume and order flow has a positive impact on exchange rate returns.

2.3.3 Economic Significance of Currency Exposure and Multiple GARCH Models

Under the new Chinese exchange rate regime, the RMB exchange rate has become more variable. Consequently, currency risk exposure has become a matter of growing interest. The seminal paper of Adler and Dumas (1984) defines the currency exposure as the sensitivity of asset price to changes in the exchange rate. In a later study, Adler et al. (1986) develop a capital market approach to examine the currency exposure issue, using the coefficient of regression on exchange rate changes and the stock returns to measure the currency exposure. De Santis and Gerard (1998) employ the multivariate GARCH model to estimate whether exchange risk significantly impacts international returns. They find that in all equity markets, excluding that of the U.S., the currency risk premium is an economically significant part of the total premium.

Doidge et al. (2006) use a portfolio approach to examine the nature of the relation between firm values and economic significance of exchange rate exposure, using data of 18 countries' non-financial firms. Their results suggest that the exchange rate plays a sizeable economic role in explaining stock returns. Muller and Verschoor (2007) assess the exchange risk exposure of Asian firms. They find that appreciation of the Asian currency against foreign currencies has a positive impact on stock returns, and vice versa.

Meanwhile, Aloui (2007) uses the multivariate EGARCH model to study the interplay between the stock price indexes and the exchange rate over the periods of EMS (European Monetary System) and EMU (European Monetary System). The results show that stock prices have a significant impact on exchange rate changes during these two periods. Wong and Li (2010) apply the DCC-GARCH model to examine the linkage between the exchange rate and the stock returns during two financial crises. Their results not only show a strong relation between stock prices and the exchange rate, but also suggest that maintaining exchange rate stability is a crucial problem during financial crises.

Meanwhile, Karunanayake et al. (2010) use the multivariate GARCH model to investigate stock market volatility during financial crises. Their results indicate that during the 1997 financial crisis the Asian countries' impact on their own market volatility was greater than their influence across markets. There is significant evidence to show that stock market volatility has been increased by the 2008 crisis. Walid et al. (2011) propose the MS-EGARCH model to explore the relation between stock market volatility and exchange rate changes in emerging market countries across the periods of two different regimes. The results demonstrate that relations

between the stock and exchange market are regime dependent; in particular, exchange rate change significantly influences the probability of regime transition. Zhang et al. (2011) apply the portfolio method to examine the currency risk exposure of Chinese firms. They find that many listed firms have significant exposure to currency risk. Chortareas et al. (2012) find evidence from three Middle East and North African countries that floating exchange rates cause abnormal returns and volatility.

This study differs from the previous studies. Specifically, this research propose application of Engel's (2002) DCC-GARCH model (Dynamic Conditional Correlation Generalised Autoregressive Conditional Heteroskedasticity) to explore the economic significance of the RMB exchange risk exposure across the global financial crisis, covering the period from 9th Dec 2009 to 9th Oct 2012.

This chapter has surveyed the research relevant to this thesis, covering the topics of exchange rate determination and dynamics, foreign exchange intervention, and exchange rate regime shifts in China. All these will be further discussed in the following chapters.

Chapter 3

Chapter 3 Microstructure of the Chinese Foreign Exchange Market

This chapter gives a general overview of the China FX market. First, this chapter review the historic evolution of China's FX market. Then, this chapter introduce the current trading system, product and service. Next, this research demonstrates the definition of order flow and its measurement. Finally, this chapter introduce the China special foreign exchange 'management' policy.

Chapter 3

Microstructure of the Chinese Foreign Exchange Market

This chapter reviews the literature relevant to this research. It contains three main parts. First, it presents an overview of the market microstructure research. Second, it reviews the intervention studies from a microstructural perspective. Finally, this chapter reviews the relevant literature on the de jure and de facto exchange rate regimes, the regime shift models and exchange rate exposure.

3.1 Historic Evolution of China's Foreign Exchange Market

The development of China's foreign exchange market has been heavily influenced by government exchange rate policy. Zhang (2001 a, b, c) shows that the main feature of China's exchange rate policy in the reform years is the adoption of a strategy that follows a variant of Corden's (1993) 'real targets' approach. The target or the mission of the exchange rate policy is to promote exports by adjusting the official exchange rate to the domestic cost of earning foreign exchange through exporting. This necessitates not infrequent changes in the nominal exchange rate, openly or covertly. With different degrees of success, the Chinese authorities have experimented with various reform efforts that aim to bring realism into China's exchange rate regime.

In December 1978, China announced its intention to reform the economic system. Before that time, the country had no financial interaction with the wider world, and very limited external trade. Since the 1970s, China's exchange rate regime has evolved in "an experiment of gradualism" (Mehran 1996). Botterlier (2004) and Huang and Wang (2004) state that the regime changed from a dual-rate system to a managed float with a de facto peg to the US dollar within a very narrow band.

Under the earlier dual exchange rate system, foreign and Chinese enterprises were permitted to trade foreign exchange with their own negotiated exchange rates in swap centres. This research created opportunities for arbitrage between swap centres. In the late 1980s and early 1990s, increasing amounts of corruption generated further market distortions. By the end of 1993 the authorities unified the official and swap market exchange rates (Truman 2008). On the first day of 1994, China adopted the managed-float regime with a narrow band. This reform process was disrupted by the outbreak of Asian financial crisis leading China to becoming cautious against excessive exchange rate fluctuations. Increasingly the Chinese currency was pegged to the US dollar. But the Chinese authorities have repeatedly stated that they are committed to allowing more flexibility to the exchange rate arrangements.

With the reforms, the Chinese foreign exchange market gradually becomes mature. In 1979, the State Administration of Foreign Exchange (SAFE) was established as a sub-institution of the Bank of China (BOC). In 1982 it became part of the central bank, i.e. People's Bank of China (PBC).

In 1978, the foreign exchange retention system was introduced. The retention schemes allowed domestic exporters to retain a certain portion of their foreign

exchange earnings, according to the quotas specified by the government. These retained foreign exchange earnings could be used to import goods and service. Two years later (1980), the BOC established trading facilities for foreign exchange retention quotas in Beijing, Guangzhou, Tianjin and Shanghai. Authorized domestic enterprises were able to transfer their quotas to other domestic enterprises at negotiated price. In parallel to the introduction of retained foreign exchange programme, the State Council introduced the renminbi (RMB) internal settlement rate for trade (ISR), effective from January 1, 1981. The ISR was established at RMB 2.8 per USD, while the official rate at that time was 1.53 per USD, implying a 83% devaluation for RMB. Foreigners meanwhile were able to get the official rate with their foreign exchange certificates (FECs).

Despite its importance as an avenue for devalue the then overvalued official exchange rate, Lin (1997) shows that ISR was not really determined by market forces. In December 1984, the PBC announced the abolishment of the ISR and the official RMB exchange rate was devalued to RMB 2.8 per USD. 1984 saw the launch of the second round of foreign exchange reform in China. In order to encourage foreign investment the Chinese government opened up major coastal areas in April. While the previous reform had sought to decentralize foreign trade management, this second round was intended to lessen government controls over foreign trade enterprises, or the trade liberalization.

Financial liberalization was also underway. With the foreign exchange retention programme, the foreign exchange swap market developed rapidly. By the end of 1988, there were 90 foreign exchange swap centres across the country. The value of transactions increased from USD 4.7 billion, to USD 86 billion in 1989, with the swap

exchange rate being more or less determined by the trading partners freely through negotiation. An IMF survey noted that after 1987, China's foreign exchange rate was under a more flexible arrangement.

From the end of 1991, the government allowed domestic individuals to participate in swap market transactions. In 1993, the number of foreign exchange swap centres increased to 108, and the swap transaction accounted for the share of China's total external transactions rose from 50% in 1991 to 80% (Lardy 1993, Zhang 2001c). On April 4, 1994 an interbank market established in Shanghai, known as the China Foreign Exchange Trading System (CFETS) and the previous swap centres were transformed into local branches of the CFETS which are linked to the Shanghai centre through a nationally integrated electronic network (see table 3.1 for Major event from 1994 to 2012).

Table 3.1 Major Events of China's Foreign Exchange Trading System

Year	Major Event
1994	<ul style="list-style-type: none"> Major reforms initiated, unification of the official and swap market rate to ¥ 8.7 per US\$. Swap market participation by domestic entities and individuals no longer permitted. Interbank market established as the CFETS based in Shanghai (April 4). Domestic firms commence purchase/sale of current account foreign exchange balances at designated foreign exchange banks. HKD/RMB trading added in the interbank FX market.
1995	<ul style="list-style-type: none"> Interbank trading in the Japanese yen commences (March).
1996	<ul style="list-style-type: none"> China accepts IMF Article VIII obligations for current account convertibility (December 1). Liberalization of foreign exchange restrictions on residents.
1998	<ul style="list-style-type: none"> Swap centres permanently closed (FFEs had been the only remaining participants).
1999	<ul style="list-style-type: none"> IMF classifies RMB exchange rate as a conventional peg (to the U.S. dollar).
2001	<ul style="list-style-type: none"> China accedes to the WTO (November 10).
2002	<ul style="list-style-type: none"> Trading in euro commences in interbank market (April).
2003	<ul style="list-style-type: none"> With approval from the SAFE, the CFETS service hours for interbank FX trading extended to 9:30-15:30. The new RMB Electronic Trading System (ET03) formally put into operation, with the F-system and the new www.chinamoney.com.cn simultaneously coming into play. Hong Kong RMB business clearing banks become members of CFETS, extending CFETS services abroad. Yearly turnover of the interbank RMB and FX markets reaches new heights, with accumulated FX market volume amounting to US\$151.13 billion and interbank lending and bond market volume amounting to 17.2 trillion Yuan.
2004	<ul style="list-style-type: none"> Bank of China (Hong Kong & Macau) Ltd. enters the national interbank FX market to adjust its position, indicating that the network and service of CFETS extends abroad for the first time. CFETS joins SWIFT. CFETS publishes the 7-day repo index as the reference index for the benchmark interest rate of the money market.
2005	<ul style="list-style-type: none"> The Bank of China Ltd. (BOC) and CFETS sign agreements on comprehensive FX cooperation. The PBOC announces the reform of the RMB exchange rate system to a managed floating exchange rate regime based on market supply and demand with reference to a basket of currencies. Interbank FX forward trading introduced.
2006	<ul style="list-style-type: none"> The PBOC announces the introduction of market makers and OTC transactions to the interbank spot foreign exchange, and authorizes CFETS to announce the central parity of RMB against US dollar, Euro, Japanese Yen and HK dollar on each business day. Interbank FX swap introduced.

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- Shanghai Interbank Offered Rate (SHIBOR) officially published.
 - Formal introduction of new generation FX trading system, which integrates products of CNY/FX spot, forward and swap and G7 currency pairs trading into a unified trading platform.
- 2007**
- Currency pairs trading introduced in the new generation FX trading system.
 - Opening ceremony of Shanghai CFET-ICAP International Money Broking Co. Ltd., a holding subsidiary of CFETS.
 - FX deposit quoting and broking system formally put into operation.
-
- 2008**
- State Administration for Foreign Exchange, Commerce Department and Customs Department jointly enact "Online Verification Method of Exchange Rate Settlement of Export", enhancing the supervision of cross-border capital flow.
-
- 2009**
- New generation of RMB trading system in spot market has launched.
 - The CFETS Market Data Service has launched for RMB part.
 - The Shanghai Clearing House has established.
-
- 2010**
- The PBOC announces to further promote the RMB exchange rate formation mechanism reform and enhance the RMB exchange rate flexibility.
 - The trading between RMB and Ringgit has started in the interbank market.
 - The closing time of interbank market adjusts to 16:30.
-
- 2011**
- The foreign exchange option start trading in the interbank market.
 - The trading between RMB and Australian dollar start trading in the interbank market.
 - The trading between RMB and Canadian dollar start trading in the interbank market.
-
- 2012**
- The RMB against U.S. dollar exchange rate floating band has widened from 0.5% to 1%.
 - The RMB against Japanese Yen can be directly trading in the interbank market.

Source: ChinaMoney. <http://www.chinamoney.com.cn/en/index.html>, last accessed on 10 May 2013.

3.2 The Current Trading System

The China Foreign Exchange Trading System (CFETS) is under the administration of the People's Bank of China (PBC) and the State Administration of Foreign Exchange (SAFE). The fundamental guidelines for its functioning are that of "adopting multiple technological means and trading patterns to meet market demands of various levels". CFETS introduced the FX trading system in April 1994, the RMB credit lending system in January 1996, interbank bond trading in June 1997, the trading information

system in September 1999 and the official website <http://www.chinamoney.com.cn> in June 2000.

RMB voice brokering began in July 2001 and the monthly periodical CHINAMONEY went into publication in October 2001. FX deposit brokering debuted in June 2002, and in June 2003 the paper quotation system was introduced. In May 2005, interbank trading in foreign currency pairs was introduced, followed in June of that year by interbank bond forward trading and in August by RMB/FX forward trading. Through the modes of electronic trading and voice brokering, CFETS provides the interbank FX market, RMB lending, bond market and paper market with trading, clearing, information and surveillance services. CFETS has played a significant role in safeguarding RMB exchange rate stability, transmitting Central Bank monetary policies, serving financial institutions and supervising market operations.

CFETS is the interbank trading and foreign exchange division of China's Central Bank. The CFETS and the National Interbank Funding Centre are subordinate to direct control of the PBC. CFETS' main functions include interbank foreign exchange trading, RMB interbank lending, bond trading, and the organization of interbank foreign exchange transactions. It also provides settlement facilities for foreign exchange transactions, delivery and settlement services for RMB interbank lending and bond trading, online bill pricing system, information services for foreign exchange, bond and money markets. With approval of the PBC, it may also initiate developing other businesses.

The CFETS has its headquarters in Shanghai and a back-up centre in Beijing. There are 18 sub-centres throughout the country, in Guangzhou, Shenzhen, Tianjin, Jinan, Dalian, Nanjing, Xiamen, Qingdao, Wuhan, Chongqing, Chengdu, Zhuhai, Shantou, Fuzhou, Ningbo, Xi'an, Shenyang, and Haikou. At the end of April 2013, the CFETS had a total of 5851 members, made up of 40 solely state-owned banks, 79 joint stock commercial banks, 3 policy banks, 149 urban commercial banks, 66 Foreign banks, 80 foreign-funded banks, 60 trust and investment companies, 492 rural credit co-operatives, 1056 corporate pensions and 88 social security funds (see Table 3.3). Its affiliated institution, the Interbank Lending Market has a total membership of 955 (see Table 3.2).

Table 3.2 Members of the National Interbank Lending Market

Financial Institution	Num.
Solely state-owned bank	35
Joint stock commercial bank	76
Policy bank	3
Urban commercial bank	122
Insurance company, Securities company	91
Foreign-funded bank, Trust & investment company	116
Rural credit co-operative	250
Rural commercial bank and cooperative bank	144
Others	118
Total	955

Source: ChinaMoney. <http://www.chinamoney.com.cn/fe/Channel/2802537>, last accessed on 10 May 2013.

Table 3.3 Members of the Chinese Foreign Exchange Trading System

Financial Institution	Num.
Solely state-owned bank	40
Joint stock commercial bank	79
Policy bank	3
Urban commercial bank	149
Foreign bank	66
Foreign-funded bank	80
Financial leasing company	18
Insurance company	113
Securities company	113
Fund	1108
Financial company	86
Rural credit co-operative	492
Trust & investment company	60
Fund management company	61
Urban credit co-operative	4
Social security fund	88
Asset management company	5
Investment company	1
Corporate pension	1056
Auto financing company	8
Others	2221
Total	5851

Source: ChinaMoney. <http://www.chinamoney.com.cn/fe/Channel/2802537>, last accessed on 10 May 2013.

3.3 Products and Services

The CFETS offers services that cover RMB/foreign currency spot trading, foreign currency/foreign currency spot trading, RMB/foreign currency forward trading, RMB interbank lending, and RMB bond trading (see Table 3.4).

Table 3.4 Products and Services of CFETS

Membership	All the banks, non-banking financial institutions and non-financial corporations that satisfy the qualifications set by the regulators for interbank FX spot trading can apply for membership of CFETS and conduct principal trading in the interbank spot FX market.		
Trading mode	Electronic matching system: members quote independently and the trade system matches the quotations in priority of price and order.		
	Over The Counter (OTC) trading system: members negotiate directly according to the principle of “bilateral credit, bilateral clearing”.		
Trading Hour (Beijing Time)		Automatic price-matching transactions	9:30 to 15:30
Monday-Friday (Chinese holidays excluded)	RMB/foreign currency spot trading	OTC transactions	9:30 to 17:30
	Foreign currency/ foreign currency spot trading		7:00 to 19:00
	RMB/foreign currency forward trading		9:30 to 17:30
	RMB interbank lending		9:00 to 12:00 13:30 to 16:30

Trading	RMB/foreign currency	USD, HKD, JPY, EUR, GBP, AUD, CAD; MYR, RUB	
	Currency	EUR/USD, AUD/USD, GBP/USD, USD/JPY, USD/CAD, USD/CHF, USD/HKD, EUR/JPY	
Clearing	RMB/ foreign	Automatic price-matching trade system	
	Currency spot trading	Centralized, two-way and netted T+2	
		OTC transactions	T+2, T+1, T+0
	For foreign currency/ foreign currency spot trading	Centralized and netted T+2	
	RMB/foreign currency forward trading	Delivery at maturity or netted delivery based on the difference between the agreed forward rate and the spot rate at maturity.	
	RMB interbank lending	Bilateral gross clearing according to the transaction notice T+ 1, T+0	
RMB bond trading	Payment after delivery Delivery after payment Delivery vs. payment		

Source: ChinaMoney, <http://www.chinamoney.com.cn/fe/Channel/2799974>, last accessed on 10 May 2013.

All financial or non-financial institutions that satisfy the regulatory qualifications can apply for membership of CFETS and conduct business accordingly. The interbank FX market employs an electronic matching system and an OTC (over-the-counter) trading

system. Members can choose either mode. For electronic matching, members quote independently and the trade system matches the quotations in priority of price and order. For OTC trading, the system provides technological facilities for members to negotiate directly on such trading factors as trading currencies, exchange rate and amount, according to the principle of “bilateral credit, bilateral clearing”.

Trading hours for RMB/ foreign currency spot trading are from 9:30 to 15:30 for automatic price-matching transactions and 9:30 to 17:30 for OTC transactions. For foreign currency/ foreign currency spot trading, the system is open from 7:00 to 19:00. The business hours for RMB/foreign currency forward trading are from 9:30 to 17:30. Finally, the RMB interbank lending operates from 9:00 to 12:00 for the morning session, followed by a lunch break, and then by an afternoon session from 13:30 to 16:30. The business hours are in Beijing time and all the transactions are open Monday to Friday, excluding Chinese holidays.

The system offers spot trading in RMB against the USD, HKD, JPY and EUR; CNY/MYR and CNY/RUB. For foreign currency/ foreign currency spot trading, the currency pairs include EUR/USD, AUD/USD, GBP/USD, USD/JPY, USD/CAD, USD/CHF, USD/HKD and EUR/JPY. A membership system applies for RMB/foreign currency forward trading. Participants are confined to those who are licensed for financial derivatives trading issued by the supervisory department.

The clearing of RMB/ FX spot trading on the automatic price-matching system follows the principles of “centralized, two-way and netted”. CFETS handles clearing for all trading members, with a clearing speed of T+2. While RMB clearing goes through the payment system of the PBC, foreign currencies are cleared through

overseas clearing systems. OTC transactions are to be settled with the clearing speed of T+2, T+1 or T+0 depending on own arrangements between the parties involved.

The foreign currency pairs business follows the “centralized and netted” principle for their clearance. The clearing speed is T+2. The forward trading in RMB/foreign currencies adopts the bilateral clearing mode, which can be either gross principal delivery at maturity or netted delivery based on the difference between the agreed forward rate and the spot rate at maturity.

The Chinese foreign exchange trading system is a computerized, real-time electronic trading system across the whole country. A digital certification centre was established in 2002, with seven relay stations in Shanghai, Beijing, Guangzhou, Shenzhen, Jinan, Tianjin and Dalian through which all members of CFETS are connected to the network. CFETS adopts a double-backup structure (in Shanghai and Beijing), while the national communication networks operated by different telecommunication companies are backups to each other.

3.4 Order Flow and its Measurement

To better our understanding of the Chinese exchange rate policy, this research follow the microstructure approach to analysing exchange rate dynamics in the Chinese foreign exchange market, as opposed to traditional macro models. At the core of this approach is the variable of order flow, which this research will first construct a new index as its proxy reflecting excess demand pressure in the Chinese foreign exchange. In a VAR modelling framework, this thesis try to answer the following questions:

- 1) Does order flow have explanatory power in the Chinese foreign exchange market?
- 2) To what extent does order flow capture the behaviour of the RMB exchange rate against international currencies, particularly the US dollar?
- 3) To what extent can order flow analysis explain the price formation process in the Chinese foreign exchange market?

Lyons (2001) points out that order flow and bid-ask spread are the core microstructure variables to transmit and reflect private information. These microstructure attributes define, respectively, the volume and price of foreign exchange transactions. In particular, order flow, as the aggregator of dispersed information regarding macro fundamentals, is the medium between macroeconomic fundamentals and exchange rates hence is the critical driving force behind exchange rate dynamics. However, this variable is not directly observable, so this research needs to construct a measure of order flow as our first step in the order flow analysis of the Chinese foreign exchange market.

3.4.1 Definition of Order Flow

O'Hara (1995, p. 1) defines market microstructure as “the process and outcomes of exchanging assets under explicit trading rules”. This definition broadly explains the microstructure approach that looks at participants in the market and their constraints in the trading process. The application of this approach to foreign exchange market has produced some promising results in explaining exchange rate changes. Central to this progress is the application of the order flow analysis.

Order flows are a variable that may reveal the ‘motive’ of the participant initiating the transaction in foreign exchange. Evans and Lyons (2002a) show that order flows provide information about the necessary risk premiums required to clear the market. They can also reflect return-relevant information that is dispersed among market participants (Evans and Lyons 2003). Given that macro statistics are an aggregate of an array of micro information and are usually announced with a lag, it is also possible such micro information may be released to the market through customer order flows. Consequently, order flows may reflect dispersed micro elements of information that will be aggregated and published as macro fundamentals. By observing order flows, market-makers who determine the exchange rate can collect such information from traders, and therefore can aggregate information, which they previously did not have, into the exchange rate (Bjønnes and Rime 2005). Empirical analysis shows that order flows are able to explain a significant part – one half to two-thirds – of the exchange rate fluctuations (Evans 2002). The following figure 3.1 shows the information processing stages.

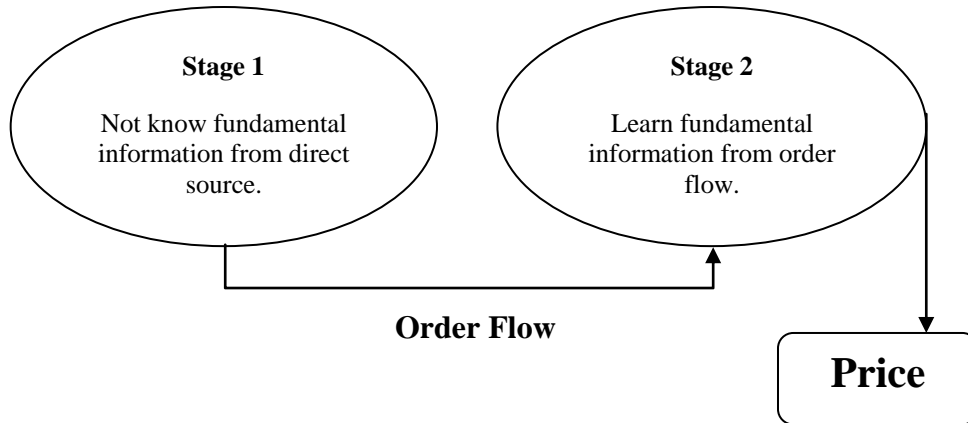


Figure 3.1 Information processing

Order flow is different from transaction volume in that it is signed (Lyons 2001). Where the initiator of the transaction is on the sell side, the order flow takes a negative sign and the order flow takes on a positive sign while the initiator is on the buyer side. Then order flow can be measured as the sum of the signed seller-initiated and buyer-initiated orders. A negative sum indicates net selling pressure over the period. Evans and Lyons (2002a, b) therefore regard order flow as the net balance of buyer-initiated and seller-initiated foreign exchange market transactions. Given its nature, order flow can be considered as an indicator of buying and selling pressure on a given currency that will affect its spot exchange rate.

3.4.2 Construction of the Measure of Order Flow

Order flows are not directly observable. One way to capture the order flow is from the transaction records (Lyons 2001). However, in the real world, confidentiality means that complete transaction records are not available to researchers. In this situation, there are two proposed methods for computing order flow. One is to estimate one

period and the next period end-user currency holdings from portfolio holdings. The other is to compare two sequential time periods, quoting price from transaction price (Evans 2011). In this section this work follow the latter method to construct measures of order flow without details of every transaction.

Order flow is transaction volume that is signed. So in order to obtain the order flow, it is necessary to get the transaction volume. In the foreign exchange market, there are two major electronic trading platforms: Thomson Reuters and the Electronic Brokerage System (EBS). Reuters generally provides data only on the number, not the volume, of trades. However, since, as shown in Bjønnes and Rime (2005) and Killen et al. (2006), analyses based on trade size and numbers of trades are not qualitatively different, our not having the trade volume should not influence the empirical analysis and results.

On the other hand, in order to figure out the order flow this work need to identify whether the trade is buyer or seller initiated, and most data do not supply the trade direction. This research now first tackle this problem by finding different methods to infer trade direction from adjacent prices and quotes.

To understand how these algorithms work, Let S_t^B and S_t^A denote the most recent bid and ask quotes for FX before a trade takes place at time t with a transaction price of S_t . There are two major methods of inferring trade direction (Evans 2011), as follows:

(1) Tick test, which use changes in trade prices to infer direction. For this test this thesis compare the previous trade price and current trade price. If the trade occurs at a higher price than the previous trade (an uptick), it is classified as a buy. If the trade occurs at a lower price than the previous trade (a downtick) it is classified as a sell.

When the price change between trades is zero (a zero tick), the trade is classified using the last price that differs from the current price. Lyons (1995) and Sias and Starks (1997) have used the tick test. The rules used to identify whether the buyer initiates the trade or seller of FX are laid out in the following table 3.5.

Table 3.5 Identification Algorithms: Tick Test

Conditions	Inference for trade at t
$S_t > S_{t-1}$	Buyer-Initiated
$S_t < S_{t-1}$	Seller-Initiated

Source: Evans (2011) , *Exchange Rate Dynamics* :Princeton University Press..

The reverse tick test is similar, but uses the next trade price to classify the current trade. If the next trade occurs on an uptick or zero uptick, the current trade is classified as a sell. If the next trade occurs on a downtick or zero downtick, the current trade is classified as a buy.

(2) The Lee and Ready Method. Lee and Ready (1991) extend the tick test to infer trade direction by comparing trade prices to quotes. For this test this research need the bid-ask price and account the midpoint price data. Trades above or below the midpoint are classified as buys or sells. Here the current transaction price, S_t , is first compared against the midpoint of the prevailing quotes, $1/2(S_t^A + S_t^B)$. If this

comparison fails to identify the initiator because $S_t = 1/2(S_t^A + S_t^B)$, the trade is then classified using the tick test. The rules used to identify whether the buyer initiates the trade or seller of FX are displayed in the following table 3.6.

Table 3.6 Identification Algorithms: Lee and Ready Test

Conditions	Inference for trade at t
$S_t > \frac{1}{2}(S_t^A + S_t^B)$	Buyer-Initiated
$S_t < \frac{1}{2}(S_t^A + S_t^B)$	Seller-Initiated
$S_t = \frac{1}{2}(S_t^A + S_t^B)$ and $S_t > S_{t-1}$	Buyer-Initiated
$S_t = \frac{1}{2}(S_t^A + S_t^B)$ and $S_t < S_{t-1}$	Seller-Initiated

Source: Evans (2011), *Exchange Rate Dynamics* :Princeton University Press.

For this research, the original foreign exchange transaction data are from Reuter 3000 Xtra. However, they only supply the 30,000 transactions price data and updated with every new tick occur. This research contributes to the literature by identifying how to use the bid and ask price in construct the index of order flow in this setting. In the definition of order flow, two things are important: trade direction and the sum of transaction volume. Evans (2011, p. 19) stated that order flow data comes in the form of the imbalance between buy and sell orders for FX: “True this is no actual order flow, but in reality it appears to be a close proxy because there is comparatively little variation in the size of individual currency orders.”

The task of this research then is to solve two major problems, i.e. finding the trading direction and summing up the tick trading direction of intraday data. This work combines the tick test with Lee and Ready's method. Take one day's data, 05/01/2009 for example. First, this work use every tick bid and ask observation to calculate every midpoint data. Second, this research compare $S_t = 6.8367(05/01/2009)$ with every midpoint data of that day. If the dealer buys, the order flow for that trade can be signed as +1. If the dealer sells, the order flow for that trade can be signed as -1. Next, depending on the situation this research use a suitable model from the above table to get each trading direction of that day, and then sum them up; for 5th January 2009 we get +372. This is called the "order imbalance" (Evans 2011). As can be seen, if this work cannot get order flow directly, period by period changes in order imbalance are the main factors driving order flow, so serial correlation in order flow closely follows that in order imbalance. Following the above algorithm, this research can construct the measure of order flow for time periods of one month and longer.

3.5 China Special foreign exchange 'Management' Policy

In this section, this research first introduces the background of the China special foreign exchange rate 'management' policy. Then, this section explains the trading mechanism of the Chinese foreign exchange market in this study.

3.5.1 The China's FX Market Intervention

From 21st June 2005, the People's Bank of China ended the fixed regime whereby the Renminbi (RMB) exchange rate was pegged to the US dollar, and began to implement a managed exchange rate regime in which the RMB is allowed to float with reference

to a basket of currencies, based on market supply and demand.² The basket currencies are selected and weighted based on the domestic and international economic situation (PBOC 2005). In this ‘managed floating’ regime, the following points apply:

- (1) To manage the international balance of payments the current and capital accounts are treated as different sets.
- (2) Foreign exchange settlement is no longer compulsory.³
- (3) Strict qualifying conditions limit the number of members of the interbank foreign exchange market in the China Foreign Exchange Trade System (CFETS). In addition, members are subject to limitation on the scale of their foreign exchange holding, and there is a restriction on the daily exchange rate fluctuation range.⁴

In order to control the daily exchange rates within crawling bands,⁵ on each business day the Central Bank announces the CPR. Under this regime, the People’s Bank of China (PBOC) in the Shanghai CFETS implements foreign exchange sterilized intervention on behalf of the Chinese government. The PBOC, as a member of

² See the People’s Bank of China official website: <http://www.pbc.gov.cn/>, last accessed on 10 May 2013.

³ On August 13, 2007, The State Administration of Foreign Exchange announced the lifting of the limit on domestic institutions’ foreign exchange accounts management. Domestic institutions are now free to retain their own current account foreign exchange incomes.

⁴ From 4th January 2006, the People’s Bank of China has announced the daily CPRs of CNY (Chinese Yuan, international term for renminbi [RMB]) against the USD on every trading day. Before business opens, the CFETS collects all the members’ quotes, cuts off the highest and lowest, and calculates the weighted average of each member’s price as the CPR of USD/CNY. The other currencies, such as CNY against EUR, JPY, HKD, GBP, MYR, RUB, AUD and CAD are calculated by cross rates between USD/CNY.

⁵ The CNY against USD used to float within a narrow band of 0.3% around the CPR published by CFETS. On 18th May 2007, this band changed to 0.5%. On 16th April 2012, the Central Bank of China changed it to 1%.

CFETS, buys and sells the Renminbi against the US dollar, euro, Japanese yuan and other major foreign currencies with the other members in the FX spot market.⁶

Table 3.7 International Balance of Payments and FX Reserves in China

International Balance of Payments and FX Reserves in China					
Year	Current Account Balance	Net Capital Inflows	Reserves Change⁷	Net Errors and Omissions	Foreign Exchange Reserves
2005	1,324	953	-2,506	229	8188.72
2006	2,318	493	-2,848	36	10663.44
2007	3,532	942	-4,607	133	15282.49
2008	4,206	401	-4,795	188	19460.30
2009	2,433	1,985	-4,003	-414	23991.52
2010	2,378	2,869	-4,717	-529	28473.38
2011	2,017	2,211	-3,878	-350	31811.48

Sources: Cumulated sum of years, in billions of US dollars. Published by *State Administration of Foreign Exchange (SAFE)*, <http://www.safe.gov.cn>, last accessed on 10 May 2013.

Table 3.7 shows China's international balance of payments and foreign exchange reserves from 2005 to 2011. As can be seen from the table, the reserve accumulation has grown rapidly in recent years. Before 2009, the current account balance is much higher than the net capital inflows. This reflects the influence of the net private capital inflows. The huge current account surplus places the exchange rate under appreciation

⁶ See China Foreign Exchange Trade System (CFETS) official website: <http://www.chinamoney.com.cn>, last accessed on 10 May 2013.

⁷ The negative sign on reserve changes means that the Chinese foreign exchange authority (SAFE) has drawn on the reserves.

pressure. In the most recent two years shown in the table, the current account becomes lower than the net capital inflows. This indicates the deficit in China and shows the impact on China of the financial crisis. However, this does not ease the upward pressure on the Renminbi (RMB). While the foreign exchange reserves have also increased rapidly over the past seven years, 2008 can be seen as a turning point. This is because, before August 2007, China applied the compulsory foreign exchange settlement system, under which only the state-regulated foreign exchange accounts could be retained, while businesses and individuals were obliged to sell their excess foreign exchange to the designated banks, and if the designated banks held foreign exchange higher than the national foreign exchange management positions, they must sell their excess foreign exchange in the interbank market. Under this system, the Central Bank was the largest in the interbank buying consortium to form the country's foreign exchange reserves. After 2008, we can find that the foreign exchange reserves follow a declining trend.

Figure 3.2 shows the relation between the monthly changes of foreign exchange reserves and exchange rate price (USD/CNY). From the figure, we can see that the foreign exchange reserves increase rapidly during these years but the exchange rate prices are fairly stable during the financial crisis period. This suggests that the Central Bank of China might have engaged in large-scale foreign exchange intervention during these years.

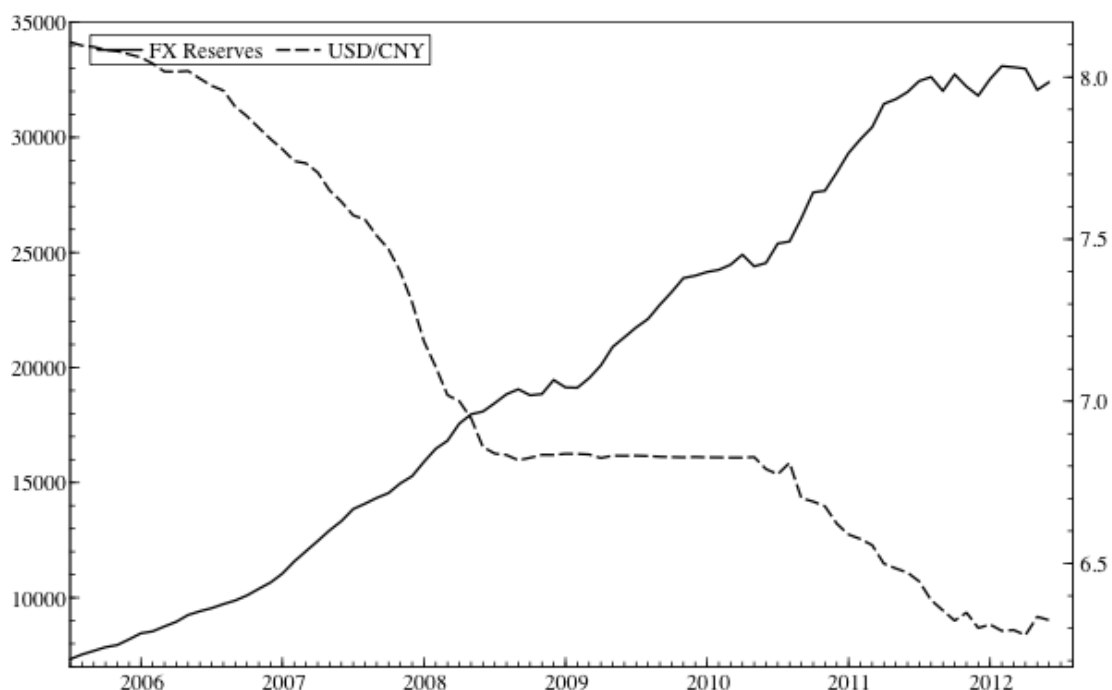


Figure 3.2 USD/CNY and China Foreign Exchange Reserves

(July 2005-July 2012)

Since the 1980s, most intervention studies have focused on the effectiveness of interventions and accuracy of intervention news reports (Menkhoff 2010). This study aims to formulate a microstructure model in the China FX spot market to illustrate the effect of Chinese government foreign exchange intervention via order flow that has information content. The research demonstrates how order flow that has information and liquidity effects transmits signals between the governing authority intervention operation and exchange rates.

3.5.2 The China's FX Market Trading Mechanism

The China spot foreign exchange markets are interbank (interdealer) markets, where authorized members can trade spot foreign currencies with other members in the China Foreign Exchange Trade System (CFETS). The People's Bank of China (PBOC) authorizes the CFETS to publish a central parity rate before the market opening time of every business day. The members usually quote bid and ask prices no more than 1% above or below this CPR.⁸ The other members can then search their fitted quotes and contact the quoted members to complete the transactions. Individual institution customers can only contact the authorized banks as dealers to trade their currencies in private. When the customer's contract or order is executed, the dealer will try to find the best quotes in the interbank RMB/FX trading system and trade with other members to release their position.

Each member can negotiate via the electronic bilateral communication system supplied by the CFETS, similar to the Reuters Dealing 3000 Spot Matching. The CFETS also centralizes limit orders; trading price, size, direction, process and member's information are available, exclusive of trader's identity. Even after the transaction is executed and cleared through the CFETS as the central trading centre, the counter parties will still not know each other's identity. This clearing method releases the credit risk, and is convenient and very suitable for extremely price sensitive users in the spot FX market.

⁸ On April 4th 2012, the People's Bank of China announced that, starting from April 16th 2012, it would extend the exchange rate floating band of the RMB against US dollar trading price from 0.5% to 1% in the interbank spot foreign exchange market.

3.6 Summary

This chapter introduces the general background of the Chinese foreign exchange market under a microstructure perspective, including historic evolutions, trading system, products and service, core concept of order flow, and special management policy. The main topics discussed in this thesis are all based on this background. Chapter 4 will discuss the exchange rate determination and dynamics in China.

Chapter 4

Chapter 4 Exchange Rate Determination and Dynamics in China: A market microstructure analysis

The aim of this chapter is to shed light on exchange rate determination in China. This research use a VAR model to investigate the relationship between order flow and exchange rate in the China FX market.

Chapter 4

Exchange Rate Determination and Dynamics in China: A market microstructure analysis

4.1 Introduction

With increasing empirical evidence showing that macroeconomic models of exchange rate determination perform poorly in capturing foreign exchange rate movements (Meese and Rogoff 1983, Frankel and Rose 1995), the market microstructure approach to the exchange rate has emerged as a new avenue to explore the forces driving exchange rate movements. Focusing on the pivotal role of order flow in the transaction process, recent theoretical and empirical works based on this approach have demonstrated that this new methodology has promising explanatory power for exchange rate changes (Evans and Lyons 2002b).

However, prior studies in this field have been primarily concerned with key currency pairs of mature economies, and little research has been conducted on the potential influence of order flow on the emerging markets.⁹ Given China's growing importance in the world economy in general and international currency relations in particular,

⁹ A notable exception is the recent work of Duffuor et al. (2012) who, by adopting the microstructure approach, examine the explanatory power of order flow in Ghanaian foreign exchange market and find that order flow has a significant, positive effect on the official exchange rate in both stable and crisis periods. Wu (2012) and Gereben et al. (2006) are two other studies on emerging markets that adopt a microstructure framework.

there is a pressing need for applying the recent research methodology to further our understanding of the Chinese exchange rate policy. The current research represents the latest attempt of such efforts.

This chapter aims to shed some light on exchange rate determination in China using a VAR model, generated within the market microstructure framework, to estimate the relationship between order flow and the exchange rate in the Chinese foreign exchange market. Specifically, this chapter seek to address the following questions:

- (1) Does the order flow help to capture the exchange rate movements of Chinese currency, the renminbi (RMB) against the US dollar as representative of China's exchange rate?
- (2) How do the long- and short-term factors influence the relative value of the Chinese currency in the foreign exchange market?

The results of this chapter's analyses are of direct interest to regulators and policy makers in evaluating the potential role of order flow in influencing the exchange rate movements and to practitioners who invest on the basis of market microstructure variables, treating them as principal indicators for future market movements.¹⁰

Furthermore, this chapter adds to the growing literature studying the determinants of foreign exchange rates in a number of ways. First, while the microstructure approach has been used to investigate exchange rate dynamics for a range of major international currency pairs (Osler 2006, Rime, Sarno, and Sojli 2010), academic studies of

¹⁰ An increasing number of studies have found evidence of a relationship between microstructure variables such as order flow and exchange rates. This idea has drawn additional support from practitioners who believe that, aside from macroeconomic factors, such as interest rates and inflation, order flow is one of the most important forces behind major exchange rate movements.

Chinese foreign exchange markets using such an important framework are limited. This lack of research is, perhaps, surprising given the importance of the Chinese markets in terms of both the volume and the value of trade and the growing popularity of the market microstructure approach to exchange rate research. Sheng (2013) notes that China has become the world's largest foreign reserve holder, with most of its holdings in the US dollar (67.3%). China is also playing an increasingly important role in the world's economy.

This study presents one of the very few attempts to fill the gap in the literature. The results obtained may be particularly relevant in providing a deeper understanding of foreign exchange market in such an important economy. Second, unlike many previous studies, this research employs a measure of country risk premium as an exogenous variable to control for the potential sources of common shocks on the exchange rate fluctuations, which appears to be another novelty in the literature.¹¹ Indeed, this may be a reason why the portion of the exchange rate movements explained by order flow is lower than what has been documented in more developed markets, but unlike previous studies in emerging markets, order flow remains a significant factor in the results.¹² Finally, this study takes into account a unique feature of emerging markets, namely, the existence of a strong government intervention and its impact on the exchange rate dynamics.

Overall, this thesis contributes to the microstructure approach to the exchange rates research by taking a closer look at the behavior of the exchange rate in China,

¹¹ Wu (2012) argue that macroeconomic variables such as the interest rates, the exchange rates, and the country risk premiums may affect the order flow. Thus, careful attention needs to be paid to these potential sources of common shocks when studying the relationship between order flow and exchange rate movement.

¹² The authors are grateful to an anonymous referee for pointing this out.

focusing on the impact of order flow on the exchange rate dynamics. This chapter first construct a measure of order flow that is based on high frequency transaction data from the Chinese market, from which the cumulative daily order flow is calculated. In addition, this research also considers the trading system reform and incorporates the consequences of market evolution into our analysis. This chapter's sample period begins with June 2010 to take into account a new "managed floating" exchange rate system re-launched in mid-2010. Furthermore, a control variable (i.e., the country risk premium) is included in the empirical model because prior studies have shown that this risk factor is an important influence of exchange rate dynamics in emerging markets.¹³ Finally, using the VAR modeling framework, this chapter investigate whether the cumulative order flow is cointegrated with the exchange rate in the Chinese foreign exchange market.

The main findings of this chapter's investigation can be summarized as follows. First, the results of this research indicate that unidirectional causality exists from order flow to exchange rate movements. Moreover, this research find that a long-term cointegrating relationship exists between the USD/CNY exchange rate and its main determinants, i.e., the order flow, the proxy for macro influences and the country risk premium. More specifically, the estimated results show that order flow not only Granger causes exchange rate movements but also is a significant determinant of the exchange rate in the short run. In this chapter's sample, order flow explains approximately 19% of exchange rate movements for every \$0.1m USD/CNY purchase. Overall, all the findings of this research are consistent with the view that in the Chinese market, order flow as a 'signed' measure of trading volume is able to

¹³ See, for instance, De Medeiros (2004) who find that the country risk premium is a significant factor in influencing the Brazilian foreign exchange market.

explain a significant proportion of fluctuations in the spot exchange rate between the Chinese RMB and the US dollar (USD/CNY).

The remainder of this chapter is organized as follows. In section two, this research outline China's exchange rate policy to establish the background for the ensuing analysis. Data and methodological issues relating to my empirical investigation are discussed in section three. Section four presents the estimation results and discusses their main implications. Finally, section five provides a summary and concluding remarks.

4.2 Foreign Exchange Market in China

The Chinese foreign exchange market is centered on the China Foreign Exchange Trading System (CFETS). Founded in April 1994, the CFETS is an institution that is under the direct control of China's central bank, the People's Bank of China (PBOC). As the central bank's interbank trading and foreign exchange division, the CFETS is authorized to organize all aspects of China's foreign exchange market under the guidelines to '[adopt] multiple technological means and trading patterns to meet market demands of various levels'. The core of the CFETS' functionality is the organization of China's foreign exchange transactions. The CFETS introduced a FX trading system in April 1994, first, for the currency pair of USD/CNY and, then, for other pairs between Chinese and other non-USD currencies and for foreign pairs between international currencies.¹⁴

¹⁴ The operation then expands to interbank short-term financing activity, with the RMB credit lending system setting up in January 1996 and interbank bond trading in June 1997. In September 1999, CFETS' trading information system was operating, and its official website launched in June 2000.

The CFETS has played a significant role in safeguarding RMB exchange rate stability, transmitting Central Bank monetary policies, serving financial institutions and supervising market operations. The voice brokering began in July 2001, FX deposit brokering debuted in June 2002, and in June 2003, and the chapter quotation system was introduced. In May 2005, interbank trading in foreign currency pairs was introduced, followed in June of that year by interbank bond forward trading and in August by RMB/FX forward trading. Through the modes of electronic trading and voice brokering, the CFETS provides the interbank FX market, RMB lending, bond market and paper market with trading, clearing and surveillance services, and with the approval of the PBOC, it may also initiate developing other businesses (see Table 3.4 in Chapter 3).

Although the CFETS has its headquarters in Shanghai and a back-up center in Beijing, there are a total of 18 sub-centers throughout the country. At the end of April 2008, the CFETS had 270 members, while its affiliated institution, the National Interbank Funding Centre (NIFC) had a total membership of 1564 as of 2010 (see Table 4.1; and for the continuation information see Tables 3.2 and 3.3 in Chapter 3).

Table 4.1 Memberships of CFETS and NIFC

Financial Institution	Number	Financial Institution	Number
Panel A: CFETS			
		Foreign-funded bank, trust & investment company	
Solely state-owned bank	5		137
Joint stock commercial bank	12	Rural credit co-operative	41
Policy bank	3	Non-banking financial institution	2
Urban commercial bank	56	Non-financial institutions	1
Authorized branch of a commercial bank	13	Total	270
Panel B: NIFC			
Solely state-owned bank	4	Financial company	57
Joint stock commercial bank	14	Rural credit co-operative	395
Policy bank	3	Trust & investment company	40
Urban commercial bank	111	Fund management company	53
Authorized branch of a commercial bank	144	Urban credit co-operative	34
Foreign-funded bank	77	Social security fund	1
Financial leasing company	4	Asset management company	5
Insurance company	82	Investment company	1
Securities company	90	Corporate pension	57
Investment fund	390	Auto financing company	1
Other	1	Total	1564

Notes: This table details the memberships of the China Foreign Exchange Trading System (CFETS) and that of its affiliated institution, the National Interbank Funding Centre (NIFC). **Source:** China Money. <http://www.chinamoney.com.cn>, last accessed on April 2010.

All financial or non-financial institutions that satisfy the regulatory qualifications can apply for membership to the CFETS and conduct business accordingly. The interbank FX market employs an electronic matching system and an OTC (over the counter) trading system. Members can choose either mode. For electronic matching, members quote independently, and the trade system matches the quotations in priorities of price and then time.

For OTC trading, the system provides technological facilities for members to negotiate directly on trading factors such as trading currencies, the exchange rates and amounts, according to the principle of ‘bilateral credit, bilateral clearing’. Trading hours for RMB/foreign currency *spot* trading (including the trading in RMB against the USD, HKD, JPY, GBP, AUD, CAD and EUR) currently are from 9:30 to 15:30 for automatic price-matching transactions and from 9:30 to 16:30 for OTC transactions. The business hours are in Beijing time, and all the transactions are open Monday to Friday, excluding public holidays.¹⁵ The business hours for RMB/foreign currency *forward* trading are from 9:30 to 17:30. A membership system applies for RMB/foreign currency forward trading, and the participants are confined to those who are licensed for financial derivatives trading issued by the supervisory department.

The clearing of RMB/FX spot trading on the automatic price-matching system follows the principles of ‘centralized, two-way and netted’. CFETS handles clearing for all trading members, with a settlement period of T+2 (two days after the transaction). While RMB settlement goes through the payment system of the PBOC, foreign currencies are cleared through overseas clearing systems. OTC transactions

¹⁵ For foreign currency/foreign currency spot trading, the system is open from 7:00 to 19:00. The currency pairs include EUR/USD, AUD/USD, GBP/USD, USD/JPY, USD/CAD, USD/CHF, USD/HKD and EUR/JPY. Finally, the RMB interbank lending operates from 9:00 to 12:00 for the morning session, followed by a lunch break, and then an afternoon session from 13:30 to 16:30.

are to be settled with the settlement periods of T+2, T+1 or T+0 depending on the arrangements between the parties involved.¹⁶ The CFETS is a computerized, real-time electronic trading system across the whole country. A digital certification center was established in 2002, with relay stations in seven major cities through which all members of CFETS are connected to the network. CFETS adopts a double-backup structure (in Shanghai and Beijing), while the national communication networks operated by different telecommunication companies serve as backups to each other.

4.3 Data and Methodology

4.3.1 Sample and Variables Constructions

Of the two major electronic trading platforms in the foreign exchange markets (EBS and Reuters), Reuters provides data not only on the number but also on the volume of trades. Thus, the original foreign exchange rate transaction data for this research is sourced from Reuter 3000 Xtra, which provides the entire Chinese market information and updated news.¹⁷ This database supplies tick-by-tick prices, including the high-frequency data for foreign exchange, futures, interest rates and other markets. In this chapter, the research focus on the Chinese foreign exchange spot market and trades from the China Foreign Exchange Trade System (CFETS). In particular, the initial dataset of this research comprises foreign exchange transactions data of the Chinese RMB against the US dollar between 8 December 2009 and 2 June 2011, covering 360 trading days. Trades are recorded for the opening hours of each working day, in

¹⁶ The trading in foreign currency pairs follows the ‘centralized and netted’ principles for settlements. The settlement period is T+2. The forward trading in RMB/foreign currencies adopts the bilateral clearing mode, which can be either gross principal delivery at maturity or netted delivery depending on the difference between the agreed forward rate and the spot rate at maturity.

¹⁷ For further information, please see *Reuters 3000 Xtra Spotlight China*.

Beijing Time (GMT+8). The opening time before 13 December 2010 is from 9:30 to 17:30. After this date, the working time changes to from 9:30 to 16:30.¹⁸ The spot exchange rate between the Chinese RMB and the US dollar (USD/CNY) P_t is the log of the exchange rate transaction price at the end of each working day's opening-time period. This dataset excludes public holidays.

The daily exchange rate movements are displayed in Figure 4.1. This figure shows that there are both oscillation and stabilizing periods during the whole sample period. Specifically, the exchange rate was almost fixed during the global financial crisis period. Therefore, this research decided to move this chapter's starting period to 21 June 2010, the date on which the PBOC announced a new "managed floating" exchange rate policy (PBOC 2010).¹⁹ The estimation period ends on 2 June 2011 when the latest data are available, and after excluding public holidays, a total of 232 observations are finally included in this sample period.

¹⁸ On 12 December 2010, the interbank foreign exchange market changed its closing time to 16:30. Initially, the order flow data are high frequency tick-by-tick data so this research converts them into the daily order flow variable.

¹⁹ On 19 June 2010 (Saturday), the PBOC announced that the RMB exchange rate fluctuation would follow a "managed floating" regime with reference to a basket of currencies (PBOC 2010).



Figure 4.1 The Daily Exchange Rate Movements, USD/CNY

Measurements of three further variables, accumulated order flow x_t , short-term interest rate differential ($i_t - i_t^*$), long-term interest rate differential ($r_t - r_t^*$), and country risk premium difference ($R_t - R_t^*$), are as follows. First, to construct a spot order flow, a value of +1 is assigned to each buy trade and -1 to each sell trade. One-day spot order flow is then equal to the sum of the trade signs over the whole working period. The daily order flow x_t is the imbalance of the buyer-initiated orders and seller-initiated orders during the opening time of the working day (Evans and Lyons 2002b). Second, the short-term interest rate differential ($i_t - i_t^*$) is the domestic daily overnight interest rate minus the foreign (US) daily overnight interest rate. The long-term interest rate differential ($r_t - r_t^*$) is the Chinese daily 12-month interbank lending interest rate minus the US daily 12-month interbank lending interest rate. These interest rate data are annualized and sourced from DataStream. In addition, this

chapter include another variable, the country risk premium. A country's daily risk premium R_t on lending is equal to the prime-lending rate²⁰ minus the 3-month Treasury bill rate.²¹ Therefore, the country risk premium difference ($R_t - R_t^*$) is the domestic minus the foreign risk premium. The descriptive statistics and correlation for the main variables of this research are reported in Table 4.2.

Table 4.2 Descriptive Statistics and Correlations of the Key Variables

	Exchange Rate P_t	Order Flow x_t	Short-term Interest Rate Differential ($i_t - i_t^*$)	Long-term Interest Rate Differential ($r_t - r_t^*$)	Country Risk Premium Difference ($R_t - R_t^*$)
Panel A: Summary Statistics					
Obs.	232	232	232	232	232
Mean	1.8940	-39.3580	0.0198	0.0265	0.1437
Std. Dev.	0.0150	23.6460	0.0107	0.0095	0.0616
Skewness	0.1416	-0.2556	2.8379	0.2346	-0.61522
Excess kurtosis	-1.1800	0.0997	9.0617	-1.5225	-1.1815
JB Normality test	25.841 [0.0000]**	2.6163 [0.2703]	616.60 [0.0000]**	67.1850 [0.0000]**	112.98 [0.0000]**
Panel B: Correlation Matrix					
P_t	1.0000	0.3005	-0.5175	-0.9605	0.8597
x_t	0.3005	1.0000	-0.1723	-0.1342	0.0485
($i_t - i_t^*$)	-0.5175	-0.1723	1.0000	0.4821	-0.3505
($r_t - r_t^*$)	-0.9605	-0.1342	0.4821	1.0000	-0.9248
($R_t - R_t^*$)	0.8597	0.0485	-0.3505	-0.9248 ²²	1.0000

Note: This table reports the descriptive statistics and correlations of the five key variables i.e., the log of spot exchange rate P_t , the order flow x_t , the short-term interest rate differential ($i_t - i_t^*$), the long-term interest rate differential ($r_t - r_t^*$) equation, and the country risk premium difference ($R_t - R_t^*$). The interest rate data are all transformed according to this formula: $\log(1 + I_t/100)$.

²⁰ This chapter use US bank prime loan and Chinese one-year lending rates.

²¹ This chapter chose China Central Bank 3-month bills and US 3-month Treasury bills (from Financial Times).

²² The correlation between the long-term interest rate differential and the country risk premium difference is high. This means the value of the long-term interest rate differential can be predicted by the value of the country risk premium difference and inclusion of the both will cause multicollinearity which will bias the estimation. Therefore, this correlation is not included in the same model for estimation when we construct the structural VAR model.

The table 4.2 shows clear evidence of a departure from normality, with most of variables failing to pass the JB normality test exclusive of order flow. The skewness for every variable under examination is under 3.²³ From the correlation matrix, we can see that the associations between the long- and short-term interest rates and the exchange rate are all negative. More important, both the order flow and the country risk premium difference have a positive relation with the exchange rate. However, the interaction among these variables may be more complex than a simple correlation can capture. It is, therefore, interesting and informative to further investigate the extent to which these key variables interact in the subsequent sections.

4.3.1.1 The Exchange Rate and Order Flow

Evans and Lyons (2002b) argue that a microstructure variable, order flow, has a strong positive correlation with the nominal exchange rate. Their original portfolio shift model is a very simple exchange rate determination model that contains the order flow information. The dynamics of exchange rates are determined by the accumulated signed order flow and by the macroeconomic information (such as changes in the interest rate differential). This model can be presented as:

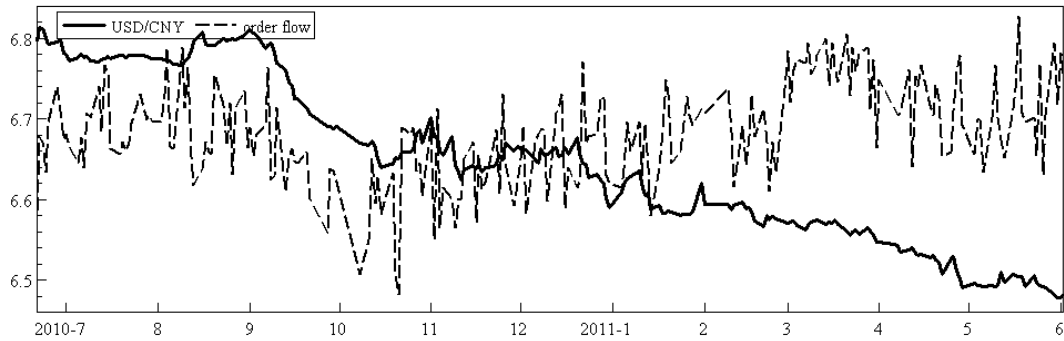
$$\Delta P_t = \alpha \Delta M_t + \beta \Delta x_t \sim I(1) \quad (4.1)$$

where ΔP_t is the log spot exchange rate changes; ΔM_t is the innovations that capture the macroeconomic information (e.g., changes in the interest rate differential); Δx_t is the accumulated signed order flow. Figure 4.2a plots the original levels of the

²³ The skewness is used to measure the symmetry of a random variable's probability distribution. It can be positive or negative (von Hippel, 2005).

exchange rate and order flow, whereas Figure 4.2b displays the log spot exchange rate (P_t) and accumulated order flow, denoted by x_t .

a)



b)

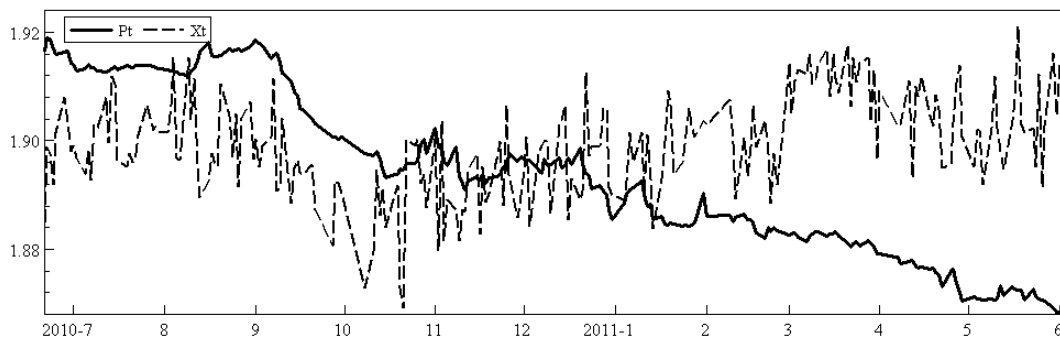


Figure 4.2 a: Chinese Exchange Rate and Order Flow, 2010/06/21-2011/06/02.

b: Log Exchange Rate and Accumulated Order Flow, 2010/06/21-2011/06/02

4.3.1.2 The Exchange Rate and Interest Rate

According to the uncovered interest rate parity (UIP), in equilibrium, the expected returns on foreign assets, measured by domestic currency, are equal to that of the domestic assets. Thus, for one period, this research has:

$$r_t = r_t^* - E\Delta p_t \quad (4.2)$$

For multiple periods, the UIP implies:

$$P_t = Ep_t + (r_t - r_t^*) \quad (4.3)$$

Considering the order flow and UIP, this model can be modified as:

$$\Delta P_t = \alpha\Delta(r_t - r_t^*) + \beta\Delta x_t + \epsilon_t \quad (4.4)$$

where P_t is the log of the exchange rate transaction price, and it is the spot exchange rate between the Chinese RMB and the US dollar. It is officially designated as USD/CNY. The macroeconomic information ΔM_t has been replaced by the change of the long-term interest rate differential $\Delta(r_t - r_t^*)$. The reason is that the interest rate not only is the major driver of exchange rate changes but also is available in daily frequency and is, hence, convenient for empirical research. Δx_t is the accumulated order flow, and ϵ_t is the error term. Figure 4.3 displays the short- and long-term interest rates and country differences in China and the US. The short-term interest rate is clearly non-stationary. The interest rates of the two countries differ greatly. Therefore, this research introduces the country risk premium for lending in our estimation.

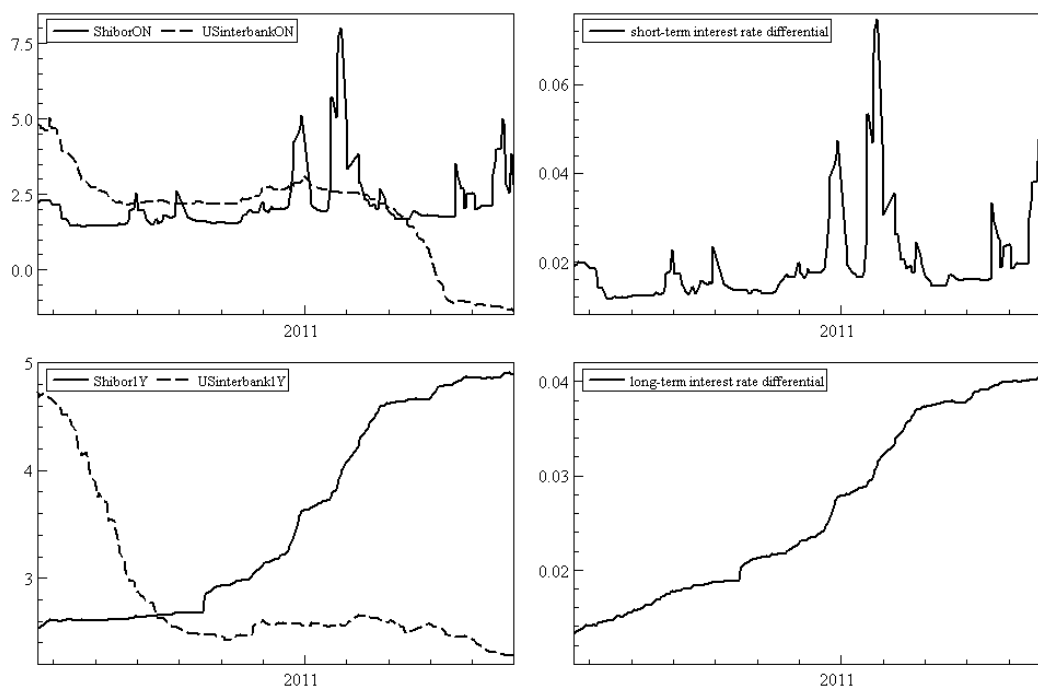


Figure 4.3 Nominal Short and Long-term Interest Rates in China and the US

4.3.1.3 Term Spread and Country Risk Difference

One contribution of our model is the introduction of an additional variable, country risk premium, which is not present in the original Evans and Lyons' (2002a, b) model. This variable is used in studies of emerging markets (Duffuor, Marsh, and Phylaktis 2012, Wu 2012). Theoretically, the external borrowing cost spread represents a marginal loan for country i during the year t . In this study, China's risk premium for lending is equal to the prime-lending rate minus the 3-month Treasury bill rate. The country risk premium difference ($R_t - R_t^*$) then is the domestic risk premium minus the foreign risk premium. Evans (2011) outlines a micro-based macro model. In the model, the risk premium reflects the fact that the two risk-averse dealers play the role of market makers rather than individual investors in the two countries' economies.

For the exchange rate of a pair of currencies, the (log) spot exchange rate P_t is determined by the settings of the short-term interest rate according to the monetary policy of the two central banks (Evans 2011). In this study, this research defines the domestic and foreign countries as China and the US, and the central banks of these two countries are the PBOC and the Federal Reserve (FED), respectively. All dealers quote a price of USD/CNY (in log) that is equal to:

$$P_t = E p_t + (i_t - i_t^*) - R_t \quad (4.5)$$

where P_t stands for the log of exchange rate; $(i_t - i_t^*)$ is the short-term interest rate differential; R_t indicates the country risk premium.

Combining equation (4.5) with equation (4.3), the long-term interest rate can be described as:

$$r_t = \frac{1}{T} \sum E_t i_t + R_t \quad (4.6)$$

Thus, the term spread between the short-term i_t and the long-term r_t is equal to:

$$(r_t - r_t^*) - (i_t - i_t^*) = (R_t - R_t^*) \quad (4.7)$$

The term spread is equal to the country risk premium difference ($R_t - R_t^*$). The term spread, the Chinese and US risk premiums and their differences are plotted in Figure 4.4.

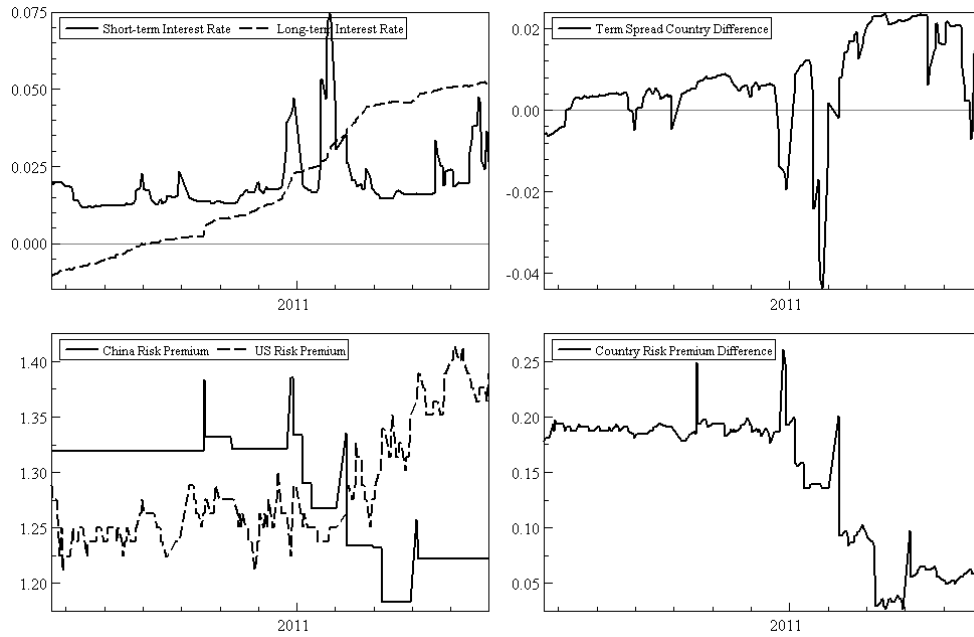


Figure 4.4 Term Spread, China and US Risk Premium and Their Differences

4.3.2 Methodological Issues

The original model developed by Lyons (1995) and Evans and Lyons (2002b) has provided a foundation for the market microstructure approach to studying the exchange rate. However, in the empirical research, criticism against the linear regression model that is used by Evans and Lyons (2002b) in their original format has emerged. This criticism is not unreasonable given that if simultaneity bias exists, their

model cannot explain it. In the context of the analysis of determinants of exchange rate movements, one should consider the feedback effect of the order flow's coefficient. In this case, a positive coefficient on order flow can be explained as either a positive exchange rate move or a positive feedback effect. Therefore, Evans and Lyons' estimation method can be inaccurate. In addition, Lyons' (1995) model is based on a single-dealer structure that is quote driven. The CFETS is, however, a multi-lateral system that is both order-driven and quote driven.

In this chapter, this research extend Evans and Lyons' (2002b) model and apply Hasbrouck's (1991) VAR framework to analyze the microstructure determinants of Chinese exchange rate movements.²⁴ The vector autoregressive model (VAR), as a system regression model implied by Sims (1980), was widely used in the recent literature (Payne 2003, Froot and Ramadorai 2005b, Danielsson and Love 2006, Wu 2012) because VAR modeling is suitable for examining not only the long-run relationship between the exchange rate and order flow but also how the long-run structure affects the short-term feedbacks. More important, it takes into account the potential feedback effect on the standard OLS regression of the order flow's coefficient.

Therefore, this research start the current research by testing the empirical implications of the portfolio shift model (Evans and Lyons 2002b) in a static framework. First, this chapter conduct a cointegration analysis with the Johansen's (1995) trace test under the VAR setting. Then, this research apply the graph-theoretic approach to examine the instantaneous causality relations between each variable (Demiralp and Hoover

²⁴ This modeling framework not only has been applied for exchange rates research but also has been commonly used to analyze the microstructure of security market (Hasbrouck 1991).

2003). Next, this chapter extend the VAR framework to estimate the explanatory power of order flow for exchange rate movement in China.²⁵

4.3.2.1 The VAR Model

Before estimating the VAR approach, this research consider the assumptions of the model:

1. The public information is immediately reflected by the quotes, and
2. The informed traders exploit their profit through using their market orders.

Let Y_t represent a vector of transaction characteristics and Z_t be the lag of each transaction characteristic, where t is an event-time observation counter. The VAR model is as follows:

$$Y_t = BZ_t + E_t \quad (4.8)$$

and,

²⁵ In the modeling process, this chapter follow the general-to-specific methodology (Hendry and Krolzig 2001) to simplify the VAR to parsimonious VAR and to examine not only the long-run relationship among the variables of interest, including that between order flow and exchange rate movements, but also the behavior of the Chinese exchange rate in terms of its short-run dynamics. See Juselius (2006) for more detailed applications.

$$Y_t = \begin{pmatrix} P_t \\ X_t \\ (i_t - i_t^*) \\ (r_t - r_t^*) \\ (R_t - R_t^*) \end{pmatrix}_{5 \times 1} ; B = \begin{bmatrix} \beta_{1,1} & K & \beta_{1,5r} \\ \vdots & \vdots & \vdots \\ M & O & M \\ \vdots & \vdots & \vdots \\ \beta_{5,1} & L & \beta_{5,5r} \end{bmatrix}_{5 \times 5r} ; \quad (4.9)$$

$$Z_t = \begin{pmatrix} P_{t-1} \\ \vdots \\ M \\ \vdots \\ R_{t-r} \end{pmatrix}_{5r \times 1} ; E_t = \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \end{pmatrix}_{5 \times 1} .$$

where P_t is the log of spot exchange rate; X_t is order flow; $(i_t - i_t^*)$ is the short-term interest rate differential; $(r_t - r_t^*)$ is the long-term interest rate differential; $(R_t - R_t^*)$ is country risk premium difference. B are the matrices of coefficients to be estimated (β , K, M, O and L). Each VAR equation is estimated by OLS with heteroscedasticity robust standard errors.

4.3.2.2 Variable Space in the VAR Specification

Alternatively, our VAR specifications can also be expressed as follows:

$$Y_t = \Gamma Y_{t-1} + \varepsilon_t \quad (4.10)$$

Thus,

$$Y_t' = [P_t \quad X_t \quad (i_t - i_t^*) \quad (r_t - r_t^*) \quad (R_t - R_t^*)] \quad (4.11)$$

As discussed, this work includes the country risk premium in the variable space when investigating the long-term relation and short-term dynamics in the system for the USD/CNY spot exchange rate. The variable P_t and the companion matrix Γ are allowed for a general number of lags and are constant across currencies. $E[\varepsilon_t \varepsilon_t'] = \Sigma$ is the covariance matrix, allowing residuals across the system equations for contemporaneous correlation.

4.4 Empirical Results and Discussions

Before estimating the VAR model outlined in section 4, this research first check the stationarity of data. The results of the augmented Dickey-Fuller (ADF) tests show that the level data cannot reject the null hypothesis of having a unit root while the first difference data can, confirming that the variables are stationary as I (1) process.²⁶

4.4.1 Cointegration Analysis

While the VAR has unique advantages as a modeling framework, a major challenge in deploying this framework is to determine the appropriate lag length for the variables in the system. Two methods for choosing the optimal VAR lag length have been suggested in the literature, one that is based on information criteria and another that is based on cross-equation restrictions. The cross-equation restriction method, however, requires the Block F-test, which would make it intractable in the VAR setting (Brooks 2008). The number of lags included in our model is, therefore, determined on the basis of three criteria (likelihood ratio test (LR), Akaike information criterion (AIC)

²⁶ The results relating to unit root tests are available from the authors on request.

and Schwarz information criterion (SC)), starting the model with a high number of lags and proceeding until the optimal number is reached.²⁷

This chapter seeks to find the relationship between the exchange rate and order flow. The results of the ADF test have confirmed that the variables are following a random walk. Therefore, this chapter applies the Johansen cointegration test. Having identified the optimal lag length to be 4, this research estimate an unrestricted VAR (4) to investigate the relation between the variables of interest using the Johansen cointegration test. The trace statistics was used as it is shown to be more robust to non-normality of errors compared with the maximal eigenvalue. The cointegration test results are reported in Table 4.3.

²⁷ This chapter considers 22 working days in a month, 10 working days in a half-month and 5 working days in a week. Thus, initially, this research set for the maximum lag length to be 22 and decrease the lag length with the unrestricted model. More specifically, by adopting the general-to-specific approach, this research omits one lag at a time (from maximum lags to 0 lag) and re-estimates the unrestricted VAR with the same sample. The results show that the optimal lag length is 4; thus, this chapter includes 4 lags of each variable in the unrestricted VAR estimation. Various diagnostic tests were also carried out and show no serious evidence of model misspecification. The results relating to the lag length selection are not presented but are available from the authors on request.

Table 4.3 Johansen Cointegration Tests

Panel A Cointegration Rank Tests					
Rank	$H_0: r \leq 0$	$H_0: r \leq 1$	$H_0: r \leq 2$	$H_0: r \leq 3$	$H_0: r \leq 4$
Eigenvalue	0.2216	0.1618	0.0791	0.0325	0.0158
Loglik	3635.184	3655.664	3665.224	3669.062	3670.911
Trace test	129.58	71.454	30.494	11.373	3.6968
Probability	[0.0000]**	[0.0090]**	[0.4790]	[0.8490]	[0.7810]

Panel B Restriction tests on cointegrating equations							
	P_t	X_t	$(i_t - i_t^*)$	$(r_t - r_t^*)$	R_t	R_t^*	Trend
Unrestricted: Strong Convergence							
β_1	0.3437	-0.0006	1.0000	4.4495	0.1712	-0.3793	-0.0004
β_2	1.0000	-0.0002	-0.0601	-0.0131	-0.2225	-0.0594	0.0002
$H_1: Trend = 0, x^2(2) = 5.8056 [0.0055]$; Strong Convergence							
β_1	3.1028	-0.0018	1.0000	5.0113	-0.3867	-0.5055	0.00
β_2	1.0000	-0.0011	-2.5377	-0.0360	-0.4325	1.2700	0.00
$H_2: P_t = -X_t, x^2(2) = 10.824 [0.0045]**$; Weak Convergence							
β_1	-0.0006	0.0006	1.0000	5.0436	0.5569	0.0709	-0.0005
β_2	1.0000	-1.0000	202.46	-13.555	-442.92	-610.49	-0.0600
$H_3: (i_t - i_t^*) = -(r_t - r_t^*), x^2(2) = 13.419[0.0012]**$; Strong Convergence							
β_1	-35.755	0.0207	1.0000	-1.0000	7.5887	0.9392	-0.0056
β_2	1.0000	0.0117	-100.93	100.93	12.284	46.280	-0.0096
$H_4: (i_t - i_t^*) = -(r_t - r_t^*), Trend = 0, x^2(4) = 19.351[0.0007]**$; Strong Convergence							
β_1	1.8437	-0.0029	1.0000	-1.0000	-1.3576	-0.2210	0.00
β_2	1.0000	-0.0003	-1.6671	1.6671	0.0080	0.7502	0.00
$H_5: R_t = -R_t^*, x^2(2) = 3.5124[0.1727]$; Strong Convergence							
β_1	1.6581	-0.0011	4.8251	22.354	1.0000	-1.0000	-0.0021
β_2	1.0000	-0.0006	-0.0730	0.1618	-0.1804	0.1804	0.0001
$H_6: R_t = -R_t^*, Trend = 0, x^2(4) = 11.439[0.0220]*$; Strong Convergence							
β_1	-1.0658	0.0021	5.6790	0.0823	1.0000	-1.0000	0.00
β_2	1.0000	-0.0006	0.1855	1.3832	-0.1016	0.1016	0.00

Notes: This table summarizes the results of Johansen cointegration tests. If r denotes the number of significant cointegration vectors, then the Johansen trace statistics test the hypotheses of at most four, three, two, one and zero cointegrating vectors. *denotes significance at the 5% level; **denotes significance at the 1% level.

As shown in Panel A of Table 4.3, the full sample contains at least two cointegrating relationships. The null hypothesis of $(H_0: r \leq 2)$ cannot be rejected at the 5% significance level. The full sample with dummy also confirms two cointegrating relationships. Given these results, this work set the cointegration rank =2 to restrict the system and form the cointegrated VAR (CVAR) to estimate the simultaneous equations within the setting of the I (0) VAR model.

The long-run cointegration coefficients are given by β , while the feedback coefficients α give the short-term adjustment speed of the deviations from the long-run equilibrium returning to the cointegrating relationship. This work test the unique cointegrating relationships in the cointegration space of the system, $Y_t' = [P_t \ X_t \ (i_t - i_t^*) \ (r_t - r_t^*) \ R_t \ R_t^* \ Trend]$. Panel B of Table 4.3 shows the test results. Hypothesis H_1 tests whether a trend exists in the cointegrating relationships, and the trend excluded in the model is rejected with the p-value of 0.0055. Hypotheses H_2 to H_6 test the long-run relations between $P_t = -X_t$ exchange rate and order flow, $(i_t - i_t^*) = -(r_t - r_t^*)$ interest rate spread, and $R_t = -R_t^*$ country risk difference in all cointegrating relationships and the joint test without trend. From the likelihood ratio (LR) test results, hypothesis H_5 is accepted with the p-value of 0.1727. It also shows that the exchange rate relates not only to the risk premium but also to the country risk difference. Thus, this chapter test long-run homogeneity cointegrating relationships in Y_t' .

Table 4.4 Hypotheses Tests on the Cointegrated Relations

Panel A Tests on the Stationarity of Single Relations							
	P_t	X_t	$(i_t - i_t^*)$	$(r_t - r_t^*)$	$(R_t - R_t^*)$	$\chi^2(1)$	Prob.
H_7	1	0	0	0	0	3.3176	[0.069]
H_8	0	1	0	0	0	2.7275	[0.099]
H_9	0	0	1	0	0	2.6407	[0.104]
H_{10}	0	0	0	1	0	3.6491	[0.056]
H_{11}	0	0	0	0	1	3.6090	[0.058]

Panel B Granger Causality Test / Long-run Weak Exogeneity					
	P_t	X_t	$(i_t - i_t^*)$	$(r_t - r_t^*)$	$(R_t - R_t^*)$
$\chi^2(4)$	8.1825	36.547	25.859	9.3057	17.900
Prob.	[0.0851]	[0.0000]**	[0.0000]**	[0.0539]	[0.0000]**

Panel C The Identified Long-run Structures					
P_t	X_t	$(i_t - i_t^*)$	$(r_t - r_t^*)$	$(R_t - R_t^*)$	LR test restrictions
β : Cointegrating Vectors					
1.9129	-0.0009	1.0000	2.7807	-0.1133	$\beta_{11} = -1$
-1.0000	0.0023	8.7879	-1.0000	1.0000	
α : Feedback Coefficients with 2 Ranks					
-0.0183	629.69	-0.0613	0.0007	0.0305	$\beta_{14} = -1$
(0.0083)	(113.30)	(0.0239)	(0.0009)	(0.0741)	$\beta_{15} = 1$
0.0009	-58.887	-0.0117	0.0003	-0.0067	$\beta_{23} = 1$
(0.0012)	(15.880)	(0.0033)	(0.0001)	(0.0104)	

Notes: This table reports the results of hypotheses tests on the cointegrated relations among our key variables. One vector restriction is applied on β in testing the stationarity. *denotes significance at the 5% level; **denotes significance at the 1% level. The trace test statistic indicates 1 cointegrating relationship at the 5 % level. The system then is restricted by cointegration rank 2. The cointegration coefficients β and adjustment coefficients α with their standard errors are all shown in () in the table. The lag interval is 1 to 4. The LR test result is $\chi^2(1) = 0.19854$ [**0.6559**].

Panel A of Table 4.4 shows the test results on the stationarity of single relations. Hypothesis H_9 states that the short-term interest rate is stationary with a p-value of 0.104. H_8 states that the order flow can be accepted as a stationary process at the 10%

significance level. This work next set the restrictions on α coefficient to test the long-run weak exogeneity in the system. In Panel B of Table 4.4, this research set the α in a zero row to find the exclusively adjusting variables in the long-run equilibrium and to identify the Granger causality. The p-values for the LR test results are quite low, suggesting that there are no weak exogenous variables for the long-run beta parameters in this system. The Granger causality test shows that order flow Granger causes exchange rate movements and that lags of order flow are significant in explaining exchange rate movement. Overall, the result shows that unidirectional causality exists from order flow to exchange rate movements of the USD/CNY.

Combining the results of all the hypotheses that this work tested, there are no fewer than two linear cointegration vectors. Taking into account the Johansen cointegration rank test and employing the Juselius (2006) modeling approach, the following cointegration vectors would be stationary cointegrating relationships:

$$X_t \sim I(0),$$

$$(i_t - i_t^*) \sim I(0),$$

$$(r_t - r_t^*) - (i_t - i_t^*) = (R_t - R_t^*) \sim I(0).$$

According to the above equations, this research test restrictions on cointegration vectors β and feedback coefficients α . There are several benefits from coefficient restrictions, such as identifying and restricting the cointegrating space. This research set the restrictions and tests them step-by-step. Thus, this work restrict the feedback coefficients to zero, the P_t coefficient to 1 in both vectors, the order flow X_t coefficients to 1 in the second vector and remove trend. The result of the LR test of

restrictions and the long-run structures are presented in Panel C of Table 4.4. The overall test statistic is $\chi^2(1) = 0.19854[0.6559]$, indicating that it is not unreasonable to impose these restrictions in the cointegrating vectors.²⁸ In addition, the results show that two cointegration equations (CIa and CIb) can be formulated for level data:

$$\begin{aligned} \text{CIa} = & -P_t + 0.0023 * X_t + 8.7879 * (i_t - i_t^*) - \\ & (r_t - r_t^*) + (R_t - R_t^*); \end{aligned} \quad (4.12)$$

$$\begin{aligned} \text{CIb} = & 1.9129 * P_t - 0.0009 * X_t + (i_t - i_t^*) + 2.7807 * \\ & (r_t - r_t^*) - 0.1132 * (R_t - R_t^*). \end{aligned} \quad (4.13)$$

From the above equations, this research find that the cointegration coefficient β on the interest differential is correctly signed and significant. The coefficient on the variable of order flow is significant and positive. Thus, the β coefficient on the order flow variable X_t is positive, which implies a higher RMB price of dollars when the net buying imbalance is higher. Given a β coefficient of 0.0023 in the USD/CNY exchange rate equation, every 1 % increase in order flow will increase the RMB price of the dollar by 23 basis points within the day.

Moreover, the variable that captures the influence of macro fundamentals—the interest differential—is signed positive. This result may reflect that the interest differential can be considered a risk-free return on currency investment if the interest rate of the dollar i_t is not changed while the interest rate of the RMB i_t^* is increased.

²⁸ The estimation results for the long-run structures presented in this table also show that there are two small eigenvalues and two significant p-values. These values determine again that the cointegration rank is 2 and this research have two cointegration equations.

Under uncovered interest parity, USD/CNY may increase to allow for dollar depreciation.

Hence, the long-run cointegration coefficient β on the interest differential is signed correctly. The long-run cointegration coefficient β on the country risk premium is also significant.

4.4.2 VAR and Error Correction Modelling

Using the long-run relationships given in equations (4.12) and (4.13) as the error correction terms, this work now turn to the formulation and the estimation of an error correction model (VECM) for the differenced variables which can be display as follows[ΔP_t ΔX_t $\Delta(i_t - i_t^*)$ $\Delta(r_t - r_t^*)$ $\Delta(R_t - R_t^*)$].

The maximum likelihood (ML) method is used to estimate our model because the system is reduced to a partial VECM, as insignificant variables were dropped from the system to reach the most parsimonious model. This method ensures the efficient and consistent parameter estimates.²⁹ The result from estimating the short-run VECM parameters for ΔP_t , ΔX_t , and $\Delta(R_t - R_t^*)$ are reported in Table 4.5.

²⁹ Hendry and Doornik (1994) explain that the reason for modeling a parsimonious VAR (PVAR) is to reduce the dependence and increase the invariance to change. Here, this chapter follow the general-to-specific method as applied by Hendry and Krolzig (2004). After this research simplifies the PVAR results, the equations show the major parts of the system. In other words, only significant lags of independent variables are kept, containing the majority of information in a much simpler model.

Table 4.5 Estimates of the Error Correlation Modelling

	ΔP_t	ΔX_t	$\Delta(R_t - R_t^*)$
Constant	0.0425 (0.0241) -0.1970**	-0.2577 (0.2410) -0.2048*	- -0.9915
α_1	(0.0648)	(0.0896) 0.2237*	(0.5740)
α_2	-	(0.0881)	- -0.9044
α_3	-	-	(0.4880)
β_1	-0.8765 (0.5674) -1.0055*	-	-
β_2	(0.4521) -0.0115	-	-
θ	(0.0064)	-0.8575** (0.0822)	- 0.6450**
φ_3	-	-	(0.1610) -11.6000*
γ_1	-	-	(5.5500) 17.9300**
γ_2	-	-	(6.1400) -21.3000**
γ_3	-	-	(4.9800) -0.3038**
δ_1	-	-	(0.0608) -0.2982**
δ_2	-	-	(0.0701) -0.1355**
δ_3	-	-	(0.0517)
R-square	0.13	0.21	0.27

Notes: This table presents the results of estimating the following short-run VECM equations, for ΔP_t , ΔX_t , and $\Delta(R_t - R_t^*)$:

$$\Delta P_t = C + \alpha_1 * \Delta P_{t-1} + \beta_1 * \Delta X_{t-1} + \beta_2 * \Delta X_{t-2} + \theta * CIB_{t-1} + \varepsilon_{p,t}$$

$$\Delta X_t = C + \alpha_1 * \Delta P_{t-1} + \alpha_2 * \Delta P_{t-2} + \theta * CIA_{t-1} + \varepsilon_{x,t}$$

$$\begin{aligned} \Delta(R_t - R_t^*) \\ = \alpha_1 * \Delta P_{t-1} + \alpha_3 * \Delta P_{t-3} + \varphi_3 * \Delta(i_{t-3} - i_{t-3}^*) + \gamma_1 * \Delta(r_{t-1} - r_{t-1}^*) + \gamma_2 * \Delta(r_{t-2} - r_{t-2}^*) + \gamma_3 \\ * \Delta(r_{t-3} - r_{t-3}^*) + \delta_1 * \Delta(R_{t-1} - R_{t-1}^*) + \delta_2 * \Delta(R_{t-2} - R_{t-2}^*) + \delta_3 * \Delta(R_{t-3} - R_{t-3}^*) + \varepsilon_{R,t} \end{aligned}$$

Standard errors are all shown in () *denotes significance at the 5% level; **denotes significance at the 1% level.

To focus first on the equation for exchange rate movement ΔP_t , this work find that the second lag of the order flow ΔX_{t-2} is significant. The coefficient on the error correction term θ is -0.0115, which shows that the short-term adjustment is negative and significant at the 10% level. The result is similar to that of unrestricted VAR, suggesting that order flow not only Granger causes exchange rate movements but also has explanatory power in capturing changes in the Chinese exchange rate in the short term. The long-run exchange rate movements influence the order flow and interest rate change in the short term.

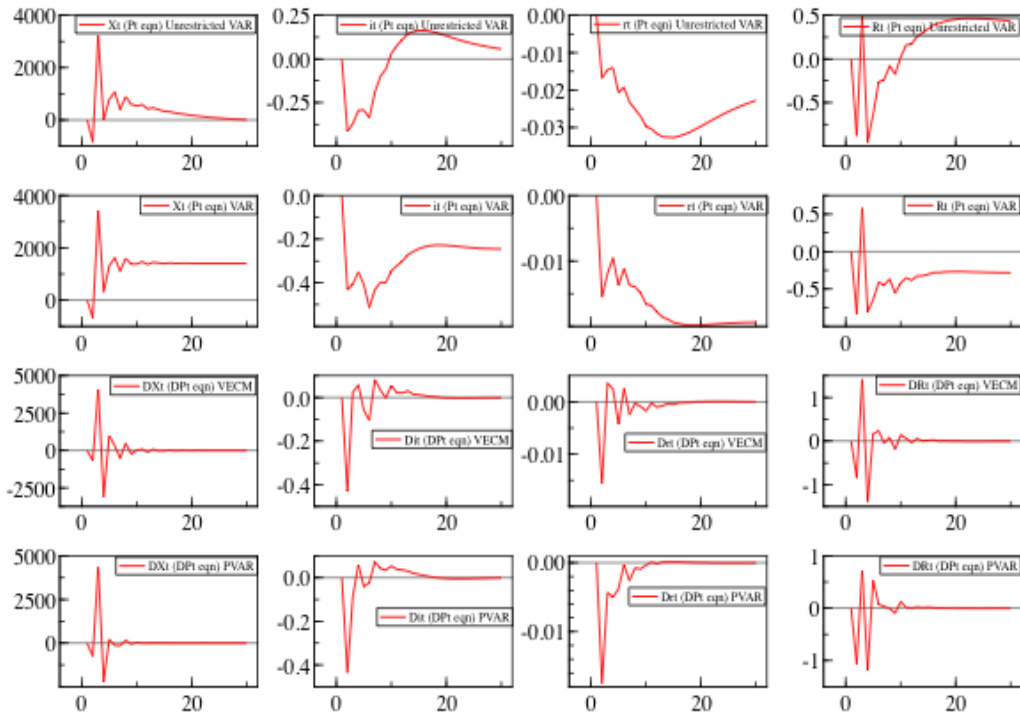
Comparing our specification with that of Evans and Lyons (2002a), although the coefficients are both significant, the R^2 of our model is lower. Evans and Lyons (2002a) get 0.64 and 0.46, but our R^2 is only 0.13. There are two possible explanations for the different results. First, as mentioned previously, in developing countries, there tends to be more government interventions in the foreign exchange market. For example, in an analysis of order flow in Brazil, De Medeiros (2004) obtained a R^2 of 0.06. Second, for the long term, not only are order flow correctly signed and significant, but this research also including the correctly signed interest rate differential and significant country risk premium.

Next, this research turn to the estimation of order flow equation. The speed of adjustment of order flow toward the long-run relationship, as given in equation (4.12), is negative and highly significant. The exchange rate movement appears to be an important factor influencing the order flow. Finally, consistent with previous findings, the country risk premium has a negative relationship with the exchange rate movement. The country risk premium also reacts significantly to the long-term

interest rate differential, as indicated by the γ coefficients and as shown before in equation (4.5).

4.4.3 Impulse Response Functions

More detailed insight on the casual relationship among the key variables can be obtained by analyzing their impulse response functions. First, this section reports the impacts of a shock to the system in different modeling configurations. Figure 4.5 shows the impulse responses to one SE (standard error) shock of each system variable in the exchange rate equation. In the figure, from the first to the fourth columns, these variables are order flow x_t , short-term interest rate differential ($i_t - i_t^*$), long-term interest rate differential ($r_t - r_t^*$), and country risk premium difference ($R_t - R_t^*$). From the first to the last rows, the impulse response functions plotted are the dynamics of unrestricted VAR, restricted form VAR, just identified VECM and parsimonious VAR (PVAR), discussed in the previous section. Comparing unrestricted VAR to PVAR, this research expects the estimated response of PVAR to be clearer and more concise to convey information about real economic phenomena.



Notes: This figure presents the impulse responses of the Chinese exchange rate to one standard error shock from the order flow (DX_t), short-term interest rate differential (Dit), long-term interest rate differential (Drt) and country risk premium (DRt). This research tests for a time horizon of 30 days.

Figure 4.5 Responses of USD/CNY to the Shocks in the Unrestricted VAR, Reduced Form VAR, Just Identified VECM and Parsimonious VAR

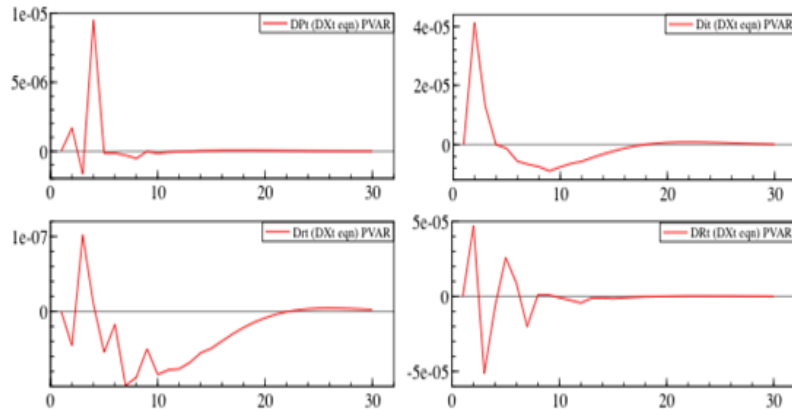
The equilibrium order flow impulse response shows the shocks of all the other variables. In the first horizon, the exchange rate responds immediately when a negative jump to order flow shocks are slightly shorter than other variables, excluding the RMB exchange rate itself. The first graph shows that the exchange rate movement occurs immediately and steadily in response to various shocks to order flow. The shock appears as a negative signal at very short horizons (first two horizons) but leads

upward to 0.22% in the long run. It appears as a feedback effect in a short time period and then becomes steady over 10 periods.

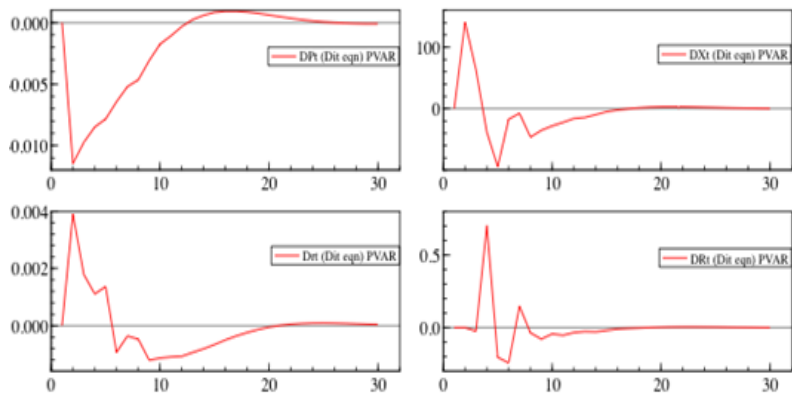
The graphs of the other three variables show that they have a different appearance when compared with the next term order flow. The results show that the proportion of the interest rate differential decreases with time. In the long horizon, the order flow has a negative influence on the interest rate differential. The interest rate, both long- and short term, has a negative sign at first and then becomes stable, declining to the origin. The interbank interest rate differential jumps in response to exchange rate shocks; at first, it has a negative sign. After 2 periods, the sign changes to a positive sign and decreases with time. If the government increases the interest rate, they should have the same sign. This will be consistent with the strict monetary policy, implying that the market may have attracted some speculators, while also being controlled by government intervention. The country risk premium shows a similar tendency but is much more flexible. In the short horizon (first five periods), the country risk difference responds immediately to exchange rate movements and more strongly and repeatedly than other variables.

Having explored the exchange rate equation, this chapter now examines the responses and dynamic simulation results of each variable in Figure 4.6.

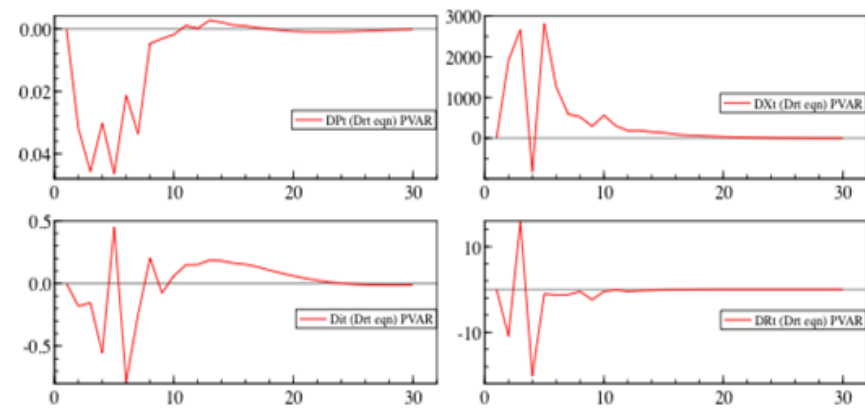
Panel A: Responses to order flow



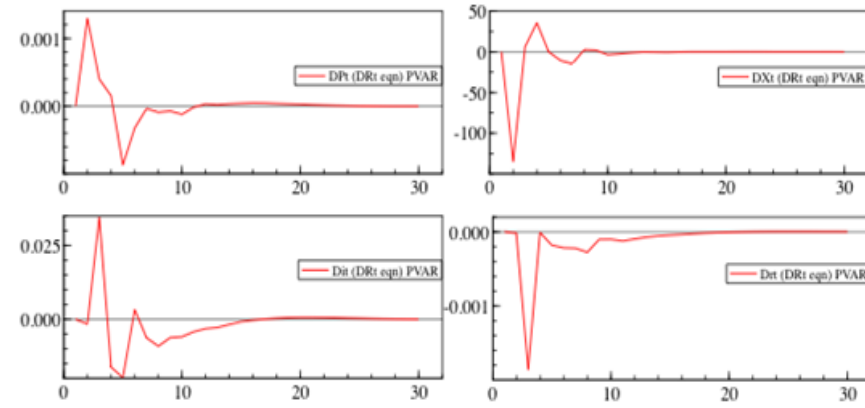
Panel B: Responses to short-term interest rate differential



Panel C: Responses to long-term interest rate differential



Panel D: Responses to country risk premium difference



Notes: This figure presents the impulse responses of each variable to one standard error shock from the order flow (DX_t), short-term interest rate differential (Di_t), long-term interest rate differential (Dr_t) and country risk premium (DR_t). PVAR denotes the Parsimonious VAR model. This research tests for a time horizon of 30 days.

Figure 4.6 Responses to Shocks in the Parsimonious VAR

The figure 4.6 shows the impulse responses of the system to one SE (standard error) shock to each variable equation, i.e., the order flow equation, short-term interest rate differential ($i_t - i_t^*$) equation, long-term interest rate differential ($r_t - r_t^*$) equation and country risk premium difference ($R_t - R_t^*$) equation, given there are two cointegrating relationships in the system. In the figures, the X-axis shows that the number of 30 steps ahead has been selected; the Y-axis shows the impact on each variable.

In the order flow equation, the exchange rate and short-term interest rate all has a positive impact on the order flow, but the effects of other variables are negative. These results are similar to the results shown in Table 4.5. For the short-term interest rate differential equation, the signs of responses are all positive except for that of the exchange rate.

However, the country risk premium has a 1.5-period delay in affecting the short-term interest rate. For the long-term interest rate differential, only the order flow has a positive impact on the long-term interest rate. All the other impulse responses are negative. Panel D of figure 4.6 shows that the country risk premium difference has a one-period delay in responding to the interest rate shocks, both short term and long term. The exchange rate and order flow have opposite impacts on country risk premium; one is positive, and the other is negative.

4.4.4 Forecast Error Variance Decomposition

Finally, in this section, this work decomposes the forecast error variance of each variable into components to account for innovation in all the variables. In general, the more exogenous a variable is, the less its forecast error variance is explained by

innovations in other variables. The variance decomposition of exchange rate movements in relation to other key variables is reported in Table 4.6.

Table 4.6 Decomposition of Exchange Rate Variance

Horizon	P_t	X_t	$(i_t - i_t^*)$	$(r_t - r_t^*)$	$(R_t - R_t^*)$	S.E.
5	90.6102	5.3382	0.1062	0.1564	3.7889	0.0027
10	83.8929	11.9628	0.06370	0.1423	3.9383	0.0040
20	78.5886	17.2970	0.1312	0.0714	3.9117	0.0059
30	76.8319	19.0794	0.1406	0.0465	3.9017	0.0074

Notes: This table presents the results of decomposing the forecast error variance of each variable into components to account for innovation in all the variables. S.E. denotes the standard error. This research tests for a time horizon of 30 days with Cholesky Decomposition.

The most exogenous variable in the system for the exchange rate appears to be order flow. The result shows that 19% of changes in the exchange rate variance are due to order flow. Thus, order flow can explain 19% of exchange rate changes within a day. Country risk premium difference accounts for 3.9% of exchange rate changes, while less than 1% is due to interbank interest rate differential. The interest rate differential has a much weaker performance than other variables in China's foreign exchange market. Hence, order flow and country risk are more influential determinants than the interest rate. Overall, changes in order flow explain more exchange rate movements than do other variables in the system.

4.5 Conclusions

This research investigates the long-term determinants and short-term dynamics of the Chinese exchange rate, with particular emphasis on the relative role of cumulative order flow. This chapter constructs a measure of daily order flow in the Chinese setting to reflect excess demand pressure in China's foreign exchange market. An additional variable, the country risk premium, is included in our investigation, along with the exchange rate, order flow and interest rate differential.

To investigate the behavior of the Chinese exchange rate in terms of its short-run dynamics and long-run equilibrium, this chapter applies a VAR framework to estimate both the long-run and short-run parameters and finds that cumulative order flow is cointegrated with the USD/CNY exchange rate in China. The results also suggest that in the new Chinese exchange rate policy regime, order flow as a 'signed' measure of trading volume explains a significant part—approximately 19%—of the short-term fluctuations in the exchange rate of the RMB against the US dollar.

In summary, this research uncovers the long term cointegrating relationship among variables under examination, including order flow, interest rates, and a proxy for macro influences. The short-run dynamics show that the fluctuations in the exchange rate of the RMB against the US dollar can be explained by a measure of excess demand pressure, i.e., the order flow. The results show that order flow has a strong and positive explanatory power in the Chinese foreign exchange market. The coefficient β on the order flow variable X_t is positive, suggesting its positive association with the RMB price of the dollar. The coefficient is 0.0023 in the RMB

equation, which implies that on a day with a 1% increase in the net purchase of dollars, the RMB price of the dollar would increase by 23 basis points.

The results of impulse responses analyses indicate that the Chinese exchange rate responds immediately and more strongly than other variables (excluding exchange rates themselves) to the changes in order flow over the short horizon. In the long term, the interest rate differential has a strong influence on exchange rate movements. Country risk premium shows a similar tendency, but to a lesser extent.

Comparing our specification with that of Evans and Lyons (2002a), this research find an interesting detail. The coefficients on order flow in our research and in their research are both significant, but our R^2 is low at 0.13, while Evans and Lyons (2002a) obtained R^2 of 0.64 and 0.46. However, our result is consistent with the findings of similar research on emerging markets, such as that in Brazil. It seems that government intervention in the emerging foreign exchange market may be the reason for this difference.

The fact that the domestic currencies of most emerging markets are not widely traded may be another reason for this difference. However, a more important reason is perhaps government over-involvement and intervention in the market. As a result, the level of the exchange rate does not move freely with market demand and supply, and the order flow consequently cannot aggregate sufficient information. In the next chapter, we will further examine the government intervention on order flow and hence its relation with the exchange rate.

Chapter 5

Chapter 5 Chinese Intervention in the Foreign Exchange Market

The chapter aims to detect the efficiency of China foreign exchange intervention with the multiple perspectives framework. This chapter also examine the action of exchange rate and order flow when intervention occurs.

Chapter 5

Chinese Intervention in the Foreign Exchange Market

5.1 Introduction

Intervention is an essential and widely used tool for central banks to direct their domestic currencies to a desirable level or to stabilize the currencies' movements. In recent years, researchers have increasingly turned their attention to study interventions in the emerging markets, where such interventions have become extensive. Menkhoff's (2013) survey reveals that foreign exchange intervention by governments of emerging market economies takes various subtle forms and is an increasingly important force in international monetary relations.

Among the emerging economies, China is particularly noted for its active intervention policy and so is the most watched internationally. The issue has become so charged that since 2005 there have been several bipartisan attempts in the US Congress to label China as a currency manipulator and to implement punitive actions accordingly.³⁰ However, despite the grave international concern and the potential

³⁰ In 2005, Senators Charles Schumer (Dem, New York) and Lindsey Graham (Republican, South Carolina) co-sponsored the first Chinese currency bill. Bipartisan efforts pushed to pass a modified bill in September 2010 in the House of Representatives and in October 2011 in the Senate. However, these later failed to become law.

global impacts, studies of China's foreign exchange intervention have been surprisingly absent. This chapter moves towards filling this critical void.

This chapter aims to achieve a better understanding of China's intervention by investigating how the Chinese monetary authority intervenes in the foreign exchange market, and the effectiveness thereof. This chapter seeks to establish how China intervenes in the marketplace, the consequences of Chinese monetary authority activity, and to what extent the interventions are effective.

Studies of foreign exchange intervention are always and everywhere a challenging task. Governments tend to cover their activity in this field with great secrecy, and this is especially so in China. Governor Zhou Xiaochuan said that the government will not return to massive intervention, as this would make exchange rate pricing a matter of politics rather than a matter of market competition (PBOC, 2012). Later, at the G20 meeting of finance ministers and central bank governors, the Chinese government further reiterated that reduced intervention will make the market play a bigger role (PBOC, 2013). In the terminology of the Chinese monetary authority, intervention is commonly referred to as 'management' of RMB exchange rates. Many covert foreign exchange activities would be concealed under the umbrella of 'currency management'. In addition to covering the research gap with regard to the existence of Chinese monetary authority intervention, this chapter makes a further contribution to the literature by identifying the dates and forms of Chinese covert intervention using a wide range of news data sources.

Based on the intervention information this research has amassed, this chapter concludes that the objective of China's intervention is to maintain the stability of the

renminbi exchange rate at an appropriate level. This intervention is built on three pillars: intervention via setting the central parity rate (CPR), which we call CPR intervention; control of the fluctuation band within which market exchange rates are allowed to move around the central parity rate; and instructions to state-owned banks to act in a direction desired by the central bank (CB) in the Chinese foreign exchange market. In some cases, there are reports that the Chinese central bank may engage directly in foreign exchange trades to tame the market. This research broadly labels such activities as CB intervention. In this light, this research makes a further contribution to the literature by refining the typology of Chinese foreign exchange interventions and examining their efficiency.

Due to issues of data availability, this chapter focuses on the CPR intervention and CB intervention. While the CPR intervention is derived from the information released by the State Administration of Foreign Exchange of China, CB intervention information is mainly detected from Reuters and Factiva. Having identified intervention dates and forms in China, this work then form a broad dataset that spans the eventful year of 2012.

This target sample period is an eventful year, as it includes, for example, the Sino-America currency dispute, a central issue in the current world economy; change of leadership in China; and general elections in the US and other countries important to China's external monetary relations. These environmental changes offer a better opportunity window for us to observe a fuller development of China's course of intervention and the consequences thereof.

This chapter adopt a multi-dimensional approach, based on high-frequency data, to explore China's intervention. A reduced form regression analysis is first conducted to consider the behaviours of the RMB exchange rate and order flow under interventions. Then, a multivariate VAR model is applied to investigate how interventions may affect dynamics of the exchange rate directly, or via its effects on order flow. This research subsequently decomposes the market movements to find out whether or not the changes are intermediated by order flow. Following Marsh (2011), this chapter examine the effectiveness of the Chinese foreign exchange intervention. A GARCH analysis is then deployed to check the robustness of our empirical findings. In the process, the tests also shed additional light on the impacts of intervention on volatility.

This thesis finds that Chinese intervention not only impacts directly on the exchange rate, but also on the buying–selling pressure. Intervention is more likely to occur when there are heavy selling orders and where the exchange rate deviates from the central bank's tolerable level one day before or on the same day. In other words, it is more likely that the Chinese authority would move to arrest currency devaluation.

Order flow is found to be positively and significantly correlated with the exchange rate when intervention occurs. Order flow carries additional information under CB intervention, while CPR intervention tends to cause a change of the impact sign when the government resorts to devaluation-targeting intervention. Decomposition analysis shows that the portion of intervention effects that is directly impounded into the exchange rate plays a more prominent role than that via the order flow. CB intervention can effectively influence both the exchange rate and order flow, while CPR intervention is effective in keeping the exchange rate within the fluctuation band. The robust test confirms the main findings of the chapter, and reveals additional

evidence that while CB intervention can influence the exchange rate and order flow, it tends to increase the volatility. Meanwhile, CPR intervention can play some role in a ‘leaning against the wind’ policy, in that it may slow the net order flow out of the dollar, but it cannot reverse the trend.

The rest of this chapter is structured as follows. In section two, this research introduces the operation of China’s intervention and discusses sources of the datasets used in this study. A critical assignment in this section concerns the identification and calculation of the CPR and CB interventions. In section three, this chapter introduce the empirical model and test the direct impact of intervention on exchange rate return and order flow separately. In section four, this research explores the effectiveness of Chinese foreign exchange market intervention. Section five discusses the robustness of the findings. Finally, in section six it presents conclusions.

5.2 Background and Data Descriptions

5.2.1 Operation of Chinese Central Bank Intervention

In an environment of growing pressure for appreciation of the Chinese currency on the ground that the RMB is claimed to be undervalued due to intervention, the Chinese government has been reluctant to admit that it has ever intervened, which may explain the secrecy around Chinese ‘management’ of exchange rate policy. From an operational standpoint, there are three major ways that China has deployed to effectuate the currency ‘management’:

- (1) Set the central parity rate and the band allowed for the fluctuation of the RMB exchange rate against the dollar;

(2) Intervention in the form of central bank instructions or guidance via the state-owned banks;³¹

(3) Direct sales or purchasing of foreign currencies by the central bank in the foreign exchange market.

Here, it is necessary to note the central bank's restrictions placed on Chinese banks with regard to foreign currency holdings. All banks must declare their positions in foreign currencies to the State Administration of Foreign Exchange (SAFE). The amount of foreign currency each bank may hold is calculated based on factors including its capital assets and transaction volume of foreign exchange settlements, etc. If a bank holds foreign currency position above the limit, it must sell the excess funds to another bank (PBOC, 2007).

Owing to the issue of data availability, this chapter concentrates on two of the above three intervention channels: the intervention via CPR (central parity rate) and the CB intervention (the direct sale or purchase of foreign currencies by the central bank). Details of the data used in the intervention analysis are described in the next subsection.

5.2.2 Data Descriptions and Statistics

This chapter select a sample that covers the eventful year of 2012 and includes data on the exchange rate, order flow, CB intervention and CPR intervention. The sample period covers 14th December 2011 to 13th December 2012, with 243 trading days excluding official holidays. This research use 24-hour news information from Factiva

³¹ Where the central bank persuades the 'big four' joint-stock banks to execute the transaction in the foreign exchange market. The 'big four' are the Bank of China, China Construction Bank, the Industrial and Commercial Bank of China and the Agricultural Bank of China. At the end of 2009 these ex-state-owned commercial banks completed joint-stock reform one after another. For details, see inter alia <http://www.pbc.gov.cn/>, last accessed on 10 May 2013.

and Reuters China. The CPR data are released before the CFETS opening time. The business day of the CFETS runs from 9:30 to 15:30 Beijing time. This section has three main parts.

Firstly, the year 2012 is chosen for the target sample period. This is because 2012 is an eventful period and provides a good fit for our studies, being the year of leadership changeover in China and in other countries.³² In particular, this year saw the US general election, in which the question of the Chinese currency was a highly charged issue. Americans wanted to ensure that China would keep her dollar assets in the US, and put pressure on the RMB to appreciate.³³ Two Asian neighbours, Japan and South Korea, also had a power changeover, which would impact on international trade and on the Chinese economy. In addition, the on-going debt crisis in the euro zone and slowdown in the world economy continued throughout 2012. These conditions make it likely that the Chinese government would intervene in the foreign exchange market to 'manage' the RMB value in 2012 more actively than in other years.

Secondly, the original data set was gleaned from three major sources. First, the tick-by-tick transaction data are from the Reuters 3000 Xtra, obtained through the China Foreign Exchange Trade System (CFETS). This research use these data to calculate the daily order flow, and use the last transaction data of every business day as the daily exchange rate data. Second, the intervention information is gained from the

³² The Chinese power changeover process started in March 2012 and climaxed in November when the 18th Party Congress closed in China.

³³ During an election campaign of at least six months in 2012, the Republican presidential nominee, Mitt Romney, declared that, if elected, the first thing he would do would be to deal with the Chinese currency, which he claimed was undervalued. President Obama took a similar hard line, with the advantage of knowledge of the under-the-table negotiations with the Chinese about China's currency. There is hearsay evidence that China had promised to do something to bid down the value of the Chinese currency.

newswire reports supplied by the online news databases, Factiva,³⁴ and Reuters China.³⁵ Third, the central parity rate is downloaded from the State Administration of Foreign Exchange (SAFE) official website.³⁶ Figure 5.1A contains the level data of the exchange rate and the accumulated order flow, and Figure 5.1B plots the main variables, including the exchange rate (USD/CNY), accumulated order flow (X_t), the CB intervention (CB INT) and the CPR intervention (CPR INT).

Thirdly, analysis in this chapter covers two sub-periods. This is because, on 13th September 2012, the US Federal Reserve announced the launch of the third round of quantitative easing (QE3) to stimulate the US economy. This controversial plan also proved to be a great stimulus to the China foreign exchange market. As can be seen from Figure 5.1A, from 13th September 2012 the RMB shows a long-lasting trend of appreciation, and order flow is quite different compared with its previous movements. Figure 5.1B also displays possible intervention movement by the Chinese monetary authority, suggesting that from 14th September 2012 the Chinese central bank intervened to stem this appreciation.

³⁴ Factiva belongs to the Dow Jones Reuters Business Interactive LLC. Formerly the Dow Jones interactive. Website: <http://www.dowjones.com/factiva/>, last accessed on 15 January 2013.

³⁵ Reuters China: <http://cn.reuters.com/>, last accessed on 15 January 2013.

³⁶ <http://www.safe.gov.cn/>, last accessed on 10 May 2013.

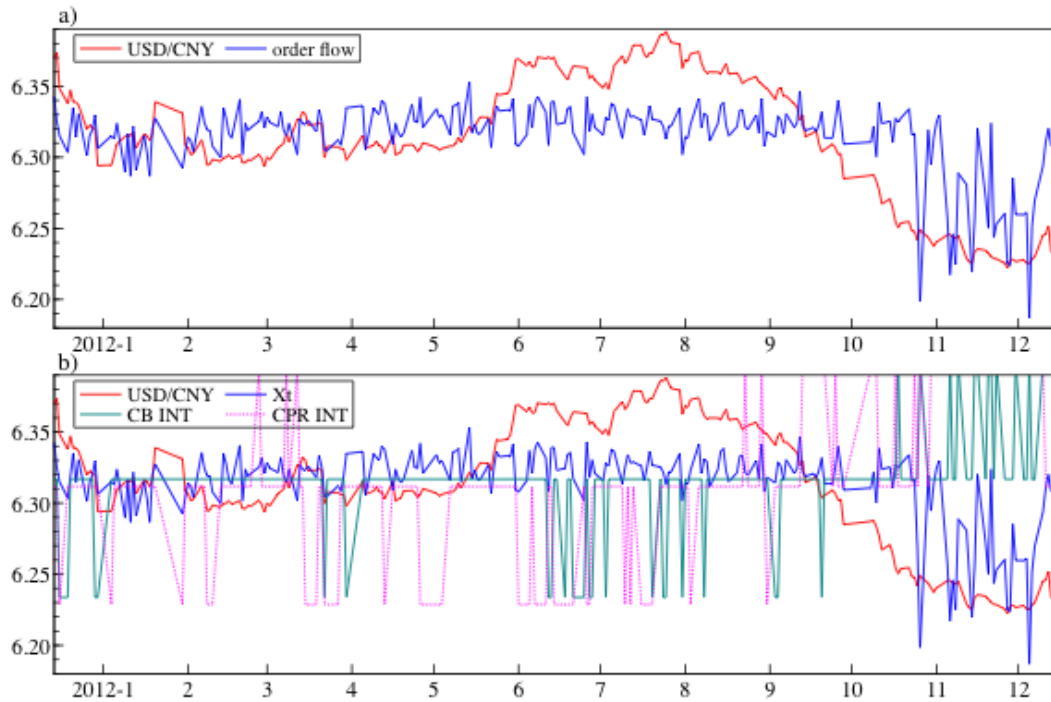


Figure 5.1 a: The exchange rate and order flow. b: Chinese exchange rate, accumulated order flow, the CB intervention and the CPR intervention

At the beginning of the period post-QE3 announcement, the CPR line shows that the monetary authority adjusted the CPR occasionally and tried to keep the RMB price stable, but this seems not to have worked. Starting from 30th October 2012 to the end of the year, the CPR was adjusted in opposite directions every day. From the CB intervention line we see that from 18th October 2012 the CB interventions were all reverse operations. In this study, this research work on the whole period and on two sub-periods. Sub-period A is from 15th December 2011 to 13th September 2012, and sub-period B is from 14th September 2012 to 13th December 2012.

5.2.2.1 The Reuters 3000 Xtra

This chapter use the tick-by-tick data from the China foreign exchange interbank market; that is, the data recorded by anyone and everyone who clicks the transaction terminals that are linked to the central processing machine of the nation. Every second, many different traders click to the CFETS transaction platform; meanwhile, other traders will reply to these trading requests through the central machine of the CFETS; these transactions are bilateral (on both demand and supply sides), since the platform matches buyers with sellers. Reuters is one of the biggest licensed vendors of CFETS data. However, the Reuters 3000 Xtra can hold and maintain data of only 30,000 transactions from the CFETS interbank foreign exchange spot market in their historical data pool. Therefore, this work download the 30,000 transaction data window first, and then collects them periodically.

Order flow is the signed transaction, defined as buyer-initiated (seller-initiated) and signed as positive (negative). Following Evans and Lyons (2002b), this research calculate order flow as daily data on the USD/CNY, the leading currency pair in the Chinese foreign exchange market. The exchange rate data are also of daily frequency, obtained from the last transaction price of each working day.

5.2.2.2 Intervention Data and the Central Parity Rate

The Chinese monetary authority does not release their intervention data directly to the public. However, based on the Chinese ‘management’ policy of foreign exchange, termed ‘managed floating within horizontal bands for the exchange rate’, this research decompose the Chinese foreign exchange intervention into the CB intervention and CPR intervention, where the former contains both direct and indirect (via the state

banks) intervention by trading activity, and the latter denotes intervention with the central parity rate.

This research detects the CB intervention information from the newswire reports supplied by Factiva and Reuters China. Following the method introduced by Beine et al. (2009) in their study of Japanese intervention, this thesis search the news reports for intervention activity. The basic rules of detecting intervention information are: First, when there is a report of direct central bank intervention this research sign this day as a CB intervention day. If the governing authority bought (sold) the USD this research sign it as +1 (-1), and otherwise as 0. Second, when it is reported that the central bank intervened via the state banks, this research also take this as a CB intervention day and the sign of intervention is marked the same as above. All degrees of certainty about the Chinese government intervention are counted into the CB intervention data: such as clearly, likely, suspected, covert, may have, think, and rumour.

For example, on 25/07/2012, when traders expected that depreciation of the RMB exchange rate would strengthen, the sale of USD by all state banks acting together indicates that the central bank wished to keep the exchange rate stable. Therefore, this thesis signs this date as -1 of CB intervention. On 10/12/2012, according to two traders, after a long period during which the RMB exchange rate remained at the upper limit, at least one state bank purchased USD and raised the price near the closing time of the market. This is suspected to be intervention of the central bank. Therefore, this thesis signs this date as 1 of CB intervention.

The RMB exchange rate against the dollar is allowed to float within a narrow band of 0.5% (1% after 16th April 2012) around the central parity rate (CPR). This research obtains the CPR intervention data in two ways: First, this research follows the above described rules to gain the CPR information from news reports. If the news report states that CPR decreases (increases), in other words USD appreciates (depreciates) while the market believes that USD should depreciate (appreciate), we mark CPR intervention as +1 (-1), otherwise 0. Second, this research compares the CPR with the close-price of the previous day. If the CPR is contrary to the prediction of the market, and is 0.45% (0.9% after 16th April 2012),³⁷ in other words 90% of the horizontal band, above/below the close-price of the previous day, it is counted as CPR intervention and signed as +1/-1, otherwise 0.

For example, on 23/03/2012, the CPR reached a new high, which is interpreted as an appreciation of the RMB exchange rate initiated by the government before a visit by Chinese leaders to the United States. Therefore, this date is signed as -1 of CPR intervention. On 23/08/2012, a trader pointed out that the increase of CPR was smaller than the overnight increase of the euro and the depreciation of USD, which could be an indication that the central bank intended to keep the exchange rate stable. Accordingly, this date is then signed as 1 of CPR intervention.

5.2.2.3 Statistics of Dataset

The statistics of the exchange rate, order flow, CB intervention and CPR intervention of the China foreign exchange market are summarized in Table 5.1.

³⁷ Before April 4th 2012, the CPR bandwidth was no more than 0.5%. Starting from April 16th 2012, the People's Bank of China extended the exchange rate fluctuation band of the RMB against the US dollar from 0.5% to 1%. Here this chapter choose 0.45% and 0.9% as our reference values.

Table 5.1 Summary Statistics of Intervention Data

	Obs.	Mean	Std. dev.	Skewness	Excess kurtosis
<i>Summary statistics</i>					
ΔP_t	242	-0.0090	0.1039	-0.6107	2.6527
X_t	242	-10.021	36.027	-2.2678	5.7498
INT_t^{CB}	37	-0.0289	0.3899	-0.2649	3.5011
INT_t^{CPR}	90	0.0331	0.6089	-0.0166	-0.3093
	ΔP_t	X_t	INT_t^{CB}	INT_t^{CPR}	
<i>Cross-correlation</i>					
ΔP_t	1.0000	0.0658	0.2178	0.0839	
X_t	0.0658	1.0000	0.2903	-0.4899	
INT_t^{CB}	0.2178	-0.2903	1.0000	0.2824	
INT_t^{CPR}	0.0839	-0.4899	0.2824	1.0000	
	First order		Second order		
<i>Serial correlation</i>					
ΔP_t		-0.0764		-0.0321	
X_t		0.6265***		0.5431***	
INT_t^{CB}		0.3198***		0.1567***	
INT_t^{CPR}		0.6768***		0.6207***	

Note: ΔP_t is 100 times log exchange rate return, X_t is order flow, INT_t^{CB} is the CB intervention, and INT_t^{CPR} is the CPR intervention. * denotes significant at 10% level, ** at 5% level and *** at 1% level.

The whole data sample comprises 242 working days. One date observation would be lost if were to take log difference of the exchange rate. According to the method

outlined above, this research can identify 37 days of CB intervention and 90 days of CPR intervention. Order flow and both types of intervention are positively correlated with log exchange rate change, while both types of intervention explain negative correlation with order flow. This implies that while intervention occurs to adjust exchange rate movements deemed undesirable by the authority, in general the Chinese central bank intervenes to stem currency appreciation. Table 5.1 also shows that all the variables except exchange rate returns display significant autocorrelation at the 1% level.

5.3 Empirical Analysis of Intervention Effects

This chapter now illustrate the intervention effects based on the empirical evidence unearthed. First, this research tests the direct impacts of intervention on exchange rate returns and order flow. Second, this research empirically analyse the sensitivity of exchange rate returns to changes in order flow under different types of interventions. In the third step, this section adopts a multivariate VAR model to establish interactions between exchange rate returns and order flow. Then, the effect of intervention on this interactive relationship is analysed. For these purposes, this section estimate a restricted VAR model to examine distinct channels through which intervention influences the exchange rate returns.

In this process, this research use the methodology introduced by Love and Payne (2008) and Frömmel, Kiss M and Pintér (2011); the data deployed in the analysis is at daily frequency. Then, as the fourth step, this section follow Marsh (2011) to test effectiveness of the interventions by adopting five main criteria for judging intervention success, with 20 subdivisions. Finally, this research estimate a GARCH

model, as introduced for example in Rincón and Toro (2010), to further explore intervention impacts, including those on volatility of exchange rate returns and order flow. Estimation of the GARCH model also provides a robust test to strengthen the empirical investigation in other parts of this chapter.

5.3.1 Reduced Form Analysis of Intervention Effects on Exchange Rate Returns and Order Flow

This section begins this research empirical investigation with two central questions, i.e. whether intervention has significant impact on exchange rate return and order flow separately, and how fast and for how long the intervention impacts occur. These questions are first investigated straightforwardly in a relatively simple model.

To capture the direct impact of intervention on exchange rate returns, this section first set up and estimates an exchange rate returns model with both types of interventions as the regressors, but excluding order flow from the model formulation. Then this research formulate an order flow model which contains order flow as a dependent variable and both types of interventions as the independent variables, while the variable of exchange rate returns is excluded. The specifications of the models are shown below:

$$\Delta P_t = \alpha + \sum_{i=-m}^m \beta_{t-i} INT_{t-i}^{CB} + \sum_{j=-n}^n \gamma_{t-j} INT_{t-j}^{CPR} + \varepsilon_t \quad (5.1)$$

$$X_t = \alpha + \sum_{i=-m}^m \beta_{t-i} INT_{t-i}^{CB} + \sum_{j=-n}^n \gamma_{t-j} INT_{t-j}^{CPR} + \eta_t \quad (5.2)$$

where ΔP_t is the log difference of the exchange rate between the Chinese RMB and the US dollar (USD/CNY) at time t (multiplied by 100), X_t is order flow at time t , INT_{t-i}^{CB} is CB intervention at time $t - i$, INT_{t-j}^{CPR} is CPR intervention at time $t - j$. m and n decide the number of lags (leads) considered in the model. This research use OLS estimation method and correct the autocorrelation and heteroskedasticity of coefficient variance/covariance matrix with the Newey-West method. The data frequency is daily. Considering that impacts of intervention may last a few days, this work take the lag lengths of both m and n as 1; i.e. this work study the effects of intervention with one day lag and one day lead.

Table 5.2 presents the estimation results of our simple model. The first three columns show the results of the exchange rate returns model regressed with the whole sample and with two sub-periods. In the whole sample from 15th Dec 2011 to 13th Dec 2012, both CB intervention and CPR intervention have significant effects on exchange rate returns on intervention days. The coefficient on CPR intervention is negatively significant at one day lag, which means CPR intervention has its effect with a one day delay. In sub-period A, from 15th Dec 2011 to 13th Sep 2012, intervention shows almost the same effect on exchange rate returns but the rebound at one day delay is weaker. In sub-period B, from 14th Sep 2012 to 13th Dec 2012, CB intervention significantly impacts exchange rate returns but CPR intervention does not.

Table 5.2 Effects of Intervention on Exchange Returns and Order Flow

	ΔP_t			X_t		
	Whole period	Sub-period A	Sub-period B	Whole period	Sub-period A	Sub-period B
α	-0.0052 (-0.90)	0.0060 (0.73)	-0.0515*** (-2.69)	-9.8841*** (-3.52)	0.9576 (0.49)	19.8749** (2.30)
β_{t-1}	-0.0300 (-1.56)	-0.0410 (-1.44)	-0.0025 (-0.10)	-3.0614 (-0.75)	-2.0955 (-0.61)	2.2303 (0.20)
β_t	0.0844*** (3.61)	0.1146*** (3.12)	0.0572*** (3.02)	-9.5954 (-1.19)	6.2388* (1.66)	-31.2934* (-1.72)
β_{t+1}	0.0106 (0.70)	-0.0049 (-0.24)	0.0380* (1.88)	-14.0619** (-2.09)	-3.3879 (-1.04)	-31.2934** (-2.11)
γ_{t-1}	-0.0371** (-2.27)	-0.0353* (-1.86)	0.0073 (0.32)	-2.7990 (-0.60)	-3.3879 (-1.04)	2.2040 (0.19)
γ_t	0.0420*** (2.88)	0.0538*** (3.04)	0.0500 (1.52)	-13.7548*** (-2.93)	-2.9150 (-0.94)	-36.8514*** (-3.35)
γ_{t+1}	-0.0234 (-1.25)	-0.0093 (0.67)	-0.0456 (-1.52)	-11.7818*** (-2.72)	-0.9593 (-0.34)	-36.2443*** (-3.28)
\bar{R}^2	0.1076	0.1206	0.1477	0.2986	-0.0079	0.3220

Note: The whole period contains a dataset from 15/12/2011 to 13/12/2012. Sub-period A is from 15/12/2011 to 13/09/2012, while sub-period B is from 14/09/2012 to 13/12/2012. α , β_{t-i} , γ_{t-j} are the constant and coefficients of intervention in equation (5.1) and (5.2), respectively. Numbers in brackets below each estimate are t-HASCE statistics; * denotes significant at the 10% level, ** at 5% level and *** at 1% level.

The last three columns of Table 5.2 present the estimation results of the order flow model. The performance of the model with the whole period is mainly determined by

sub-period B, while most coefficients in sub-period A are not significant; the exception is CB intervention. Although both CB and CPR interventions show almost the same effects on exchange rate returns, their impacts on order flow are different in the two sub-periods. The coefficient on CB intervention in sub-period A is positive though weakly significant, which means that government purchases or sales of foreign exchange may influence order flow, which in turn pushes exchange rate movements. In contrast, the coefficients on CB intervention and CPR intervention in sub-period B are negatively significant and exhibit one day lead effect on order flow.

As can be seen from Figure 5.2, in sub-period B the market expects the US dollar to depreciate against the RMB and in response there is a large number of selling orders. After October 2012, the exchange rate frequently hits the limits of the CPR fluctuation band. Intervention is then expected to occur, and this is also associated with deviations from the central bank's tolerable level one day before or on the same day. CB intervention plays a role of liquidity provider and passively attenuates order flow, while CPR intervention is a tool to enforce exchange rate movements no matter how large the selling orders are. In the empirical examination of this research, this section also find that CB intervention is only effective on the day it occurs, while CPR intervention has a one day delay but shows a weak trend of rebound. The delayed effect appears in the exchange rate return equation but not the order flow equation.

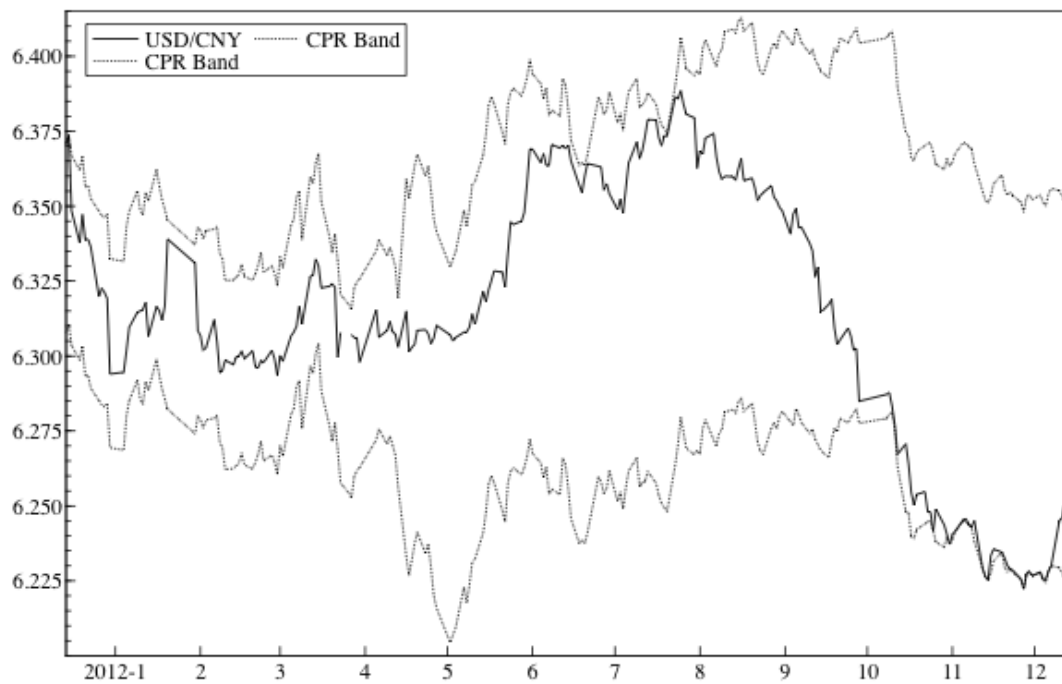


Figure 5.2 Evolution of Exchange Rate Movements and CPR Fluctuation Band

5.3.2 Sensitivity Analysis

As has been reported above, intervention not only impacts directly on exchange rate returns, but also affects the buying – selling pressure, or order flow. Our findings for sub-period A are consistent with the news effects studied by Love and Payne (2008) and Frömmel, Kiss M and Pint é (2011). However, the sign of intervention effect on order flow is opposite in sub-period B. In this sub-section this research explore further the market behaviour in China under the influence of intervention. Following Frömmel, Kiss M and Pint é (2011) this research formulate the following model for our investigation:

$$\Delta P_t = \alpha + \beta_t X_t + \gamma_t X_t I(INT_t^{CB}) + \delta_t X_t I(INT_t^{CPR}) + \varepsilon_t \quad (5.3)$$

where, $I(INT_t^{CB})$ and $I(INT_t^{CPR})$ are dummy variables when CB intervention and CPR intervention respectively occur. Equation (5.3) distinguishes the influence of order flow on exchange rate when intervention occurs from that where there is no intervention. This work introduces a benchmark model which contains order flow only in the exchange rate return equation. The comparison will allow us to acquire insights into the behaviour of order flow when intervention occurs. This section's estimated results are shown in Table 5.3.

Table 5.3 Sensitivity Analysis of Order Flow to Intervention

	Whole Period (15/12/2011-13/12/2012)		Sub-period A (15/12/2011-13/09/2012)		Sub-period B (14/09/2012-13/12/2012)	
	Benchmark	Equation (5.3)	Benchmark	Equation (5.3)	Benchmark	Equation (5.3)
α	-0.0071 (-1.13)	-0.0101 (-1.57)	-0.0054 (-0.76)	-0.0028 (-0.40)	-0.0426*** (-3.30)	-0.0416*** (-3.07)
β_t	0.0002 (1.26)	0.0020*** (3.92)	0.0017*** (3.21)	0.0014** (2.19)	-0.0004*** (-3.26)	0.0016* (1.80)
γ_t		-0.0001 (-0.47)		0.0043* (1.67)		-0.0003 (-1.09)
δ_t		-0.0020*** (-3.82)		-0.0008 (-0.73)		-0.0019** (-2.06)
\bar{R}^2	0.0002	0.0544	0.0637	0.1004	0.0316	0.069

Notes: α , β_t , γ_t , δ_t are the constant and coefficients to be estimated in equation (5.3). The first row in every equation is the estimated value of constant and coefficients; numbers in brackets below each estimate are t-HASCE statistics; * denotes significant at 10% level, ** at 5% level and *** at 1% level.

It can be seen that in the regression results for the whole sample period, order flow is not significant in the benchmark model. However, when this research introduces the sensitivity parameter of order flow to the CPR intervention model, order flow becomes significant and positively correlated with exchange rate returns. Similarly, while the coefficient on order flow looks wrong-signed (negative) and significant in the benchmark model, it becomes positive though weakly significant in the estimation results of equation (5.3). The sum of coefficient β_t and δ_t is quite close to the coefficient on order flow in the benchmark model, which suggests that the wrong sign of order flow is due to the existence of CPR intervention. Without CPR intervention, every 1% increase of order flow is associated with an increase in the exchange value of the RMB against the dollar by 20 basis points (16 basis points in sub-period B). When CPR intervention occurs, order flow changes its impact direction to decrease the exchange value of USD/CNY. The final effect of order flow therefore disappears and is even dominated by wrong-signed order flow. The adjusted R-sq for the whole period is relatively low. It is plausible that the sub-period B influences the performance of the whole period. In addition, the effect of order flow only changes under CPR intervention when the exchange rate is close to the limits of the CPR fluctuating band, while δ_t is not significant in sub-period A.

In sub-period A, order flow is positive and significant in the exchange rate determination. This is consistent with the previous literature, for example the findings of Evans and Lyons (2002b) with regard to USD/JPY and USD/DEM. When CB intervention occurs, the effect of order flow on exchange rate significantly changes. Every 1% increase of net buying of the US dollar will lead to an additional 29 basis points increase of the exchange rate compared to the case without CB intervention.

This indicates that order flow carries additional information when CB intervention is discovered.

5.3.3 Intervention Impacts on Exchange Rate Returns and Order Flow in a VAR Setting

Having analysed impacts of CB intervention and CPR intervention on exchange rate movements and order flow in different sample periods, this chapter now move to explore whether the exchange rate reacts to these two different interventions directly or indirectly, that is, intermediated by order flow. For this purpose, this section needs to investigate the interactions between the exchange rate and order flow when intervention occurs.

5.3.3.1 The VAR Model

This research set up a VAR model that includes CB and CPR interventions, the exchange rate and order flow in its variable space. The model specification is as follows:

$$AY_t = C + BY_{t-1} + \theta INT_t + E_t \quad (5.4)$$

and,

$$\begin{aligned}
A &= \begin{bmatrix} \alpha_{1,1} & \alpha_{1,2} \\ \alpha_{2,1} & \alpha_{2,2} \end{bmatrix}_{2 \times 2}; Y_t = \begin{pmatrix} \Delta P_t \\ X_t \end{pmatrix}_{2 \times 1}; \\
B &= \begin{bmatrix} \beta_{1,1} & \cdots & \beta_{1,2i} \\ \beta_{2,1} & \cdots & \beta_{2,2i} \end{bmatrix}_{2 \times 2i}; Y_{t-1} = \begin{pmatrix} \Delta P_{t-1} \\ \vdots \\ M \\ \vdots \\ X_{t-i} \end{pmatrix}_{2i \times 1}; \\
\theta &= \begin{bmatrix} \theta_{1,1} & \theta_{1,2} \\ \theta_{2,1} & \theta_{2,2} \end{bmatrix}_{2 \times 2}; INT_t = \begin{pmatrix} INT_t^{CB} \\ INT_t^{CPR} \end{pmatrix}_{2 \times 1}; E_t = \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \end{pmatrix}_{2 \times 1}
\end{aligned} \tag{5.5}$$

where, ΔP_t is the log difference of the exchange rate; X_t is order flow; INT_t^{CB} is CB intervention and INT_t^{CPR} is CPR intervention. A and B are the coefficients matrices of lagged variables to be estimated; θ is the structural effects of interventions; E_t is the covariance matrix; C is constant.

The reduced form uses the A^{-1} to multiply the structural VAR model, both sides of equation (5.4). Here the reduced form VAR can be displayed as:

$$Y_t = \lambda + \Gamma Y_{t-1} + \Theta INT_t + H_t \tag{5.6}$$

where, $\lambda = A^{-1}C$; $\Gamma = A^{-1}B$; $\Theta = A^{-1}\theta$ and $H_t = A^{-1}E_t$.

The coefficients on interventions are $\Theta = A^{-1}\theta$. The matrix A , or the off-diagonal elements, can be retrieved from the estimation of the structural parameters. Thus, the structural form intervention impact, θ , is from the conditional covariance matrix of reduced form Θ , such that $\theta = A\Theta$. The coefficient on the structural form intervention impact could tell us the effect of intervention on the exchange rate intermediated by

order flow. Here, this research follow Frömmel, Kiss M and Pint é (2011), and do not consider the simultaneous feedback trading in this chapter's sample.

There are two assumptions essential to our empirical modelling: first, the error term of the structural form is zero covariance; second, set $\alpha_{2,1}$ of matrix A in equation (5.5) is equal to zero. The final multivariate VAR model is as follows:

$$\begin{pmatrix} \Delta P_t \\ X_t \end{pmatrix} = \lambda + \begin{pmatrix} -\alpha_{1,2} \\ 0 \end{pmatrix} X_t + \Gamma_{2 \times 2} \begin{pmatrix} \Delta P_{t-1} \\ X_{t-1} \end{pmatrix} + \Theta_{2 \times 2} \begin{pmatrix} INT_t^{CB} \\ INT_t^{CPR} \end{pmatrix} + \eta_t \quad (5.7)$$

where, ΔP_t is log difference of the exchange rate; X_t is order flow; INT_t^{CB} is CB intervention; INT_t^{CPR} is CPR intervention. In this formulation, the contemporaneous order flow is on the left hand side of the reduced form exchange rate equation.

All the equations in the system are estimated with OLS; the residuals are estimated by the ML (maximum likelihood). For every sample, the optimal lag is set to be one. The lag length choice method is guided by the SC (Schwarz information criterion) and HQ (Hannan-Quinn information criterion).

5.3.3.2 Estimation Results of the VAR model

Table 5.4 reports the estimates of order flow and exchange rate returns in the VAR analysis. The results of the coefficients on the intervention variables can be summarized as follows: First, the coefficients on the CB intervention in the exchange rate equation are positive and significant in every sample set. In the whole sample period, one unit of central bank intervention directly causes USD/CNY appreciation

of 6.10 basis points. In sub-period A this increases to 9.83 basis points, while sub-period B has appreciation of 4.77 basis points (significant at 10% level). Second, the reduced form coefficients on both CB and CPR interventions in the order flow equation have wrong signs in sub-period B. This seems to be caused by poor liquidity of the Chinese foreign exchange market during sub-period B. Third, the coefficients on CPR intervention are significant only in the equation where order flow is excluded in sub-period A. The aim of CPR intervention in general is to prevent a too rapid increase in the RMB price. This seems to work with regard to order flow, but still cannot influence the RMB appreciation trend. This could be because the performance of the whole period is mainly determined by the performance in sub-period B, during which, as previous reports show, the Chinese foreign exchange market has poor liquidity. In contrast, in sub-period A the CPR intervention directly causes 3.38 basis points of USD/CNY rate appreciation.

The reduced form adjusted R^2 shows that the regression results of the exchange rate equation have less explanatory power than the results of the order flow equation. The adjusted R^2 in the order flow equation is nearly 28% on average while the explanatory power of the exchange rate equation is 25%. Compared to the results in Table 5.2, the reduced form of the VAR model has a better performance and greater explanatory power.

Table 5.4 VAR Analysis of Order Flow and Exchange Rate Returns

	Whole Period		Sub-period A		Sub-period B	
	(15/12/2011-13/12/2012)		(15/12/2011-13/09/2012)		(14/09/2012-13/12/2012)	
	ΔP_t	X_t	ΔP_t	X_t	ΔP_t	X_t
Constant	-0.0076 (-1.10)	-4.7947*** (-2.60)	0.0138 (1.62)	1.0966 (0.80)	-0.0783*** (-3.41)	4.5156 (0.42)
INT_t^{CB}	0.0610*** (3.34)	-4.4663 (-0.92)	0.0983*** (4.17)	5.9715 (1.56)	0.0477* (1.74)	-17.4793 (-1.36)
INT_t^{CPR}	0.0046 (0.37)	-14.6100*** (-4.46)	0.0338** (2.12)	-2.4241 (-0.94)	0.0315 (1.08)	-32.7807** (-2.39)
\bar{R}^2	0.0419	0.4365	0.1030	0.0102	0.1067	0.3830
OF_t	-0.000678*** (-2.85)	—	-0.001616*** (-3.66)	—	-0.0000737 (-0.27)	—
ΔER_t	—	0	—	0	—	0
$INT_t^{CB} Struck$	0.0641	—	0.0886	—	0.0490	—
$INT_t^{CPR} Struck$	0.0145	—	0.0377	—	0.0339	—

Notes: ΔP_t is log difference of the exchange rate; X_t is order flow; INT_t^{CB} is CB intervention; INT_t^{CPR} is CPR intervention; OF_t is the effect of order flow on exchange rate returns in the exchange rate equation, retrieved from the conditional variance estimation; ΔER_t is the effect of exchange rate returns on order flow in the order flow equation. Given that no feedback trading is allowed in China, here we restrict it to zero. $INT_t^{CB} Struck$ and $INT_t^{CPR} Struck$ are coefficients on the structural CB and CPR interventions, indicating their impacts in the exchange rate return equation. * Denotes significant at 10% level, ** at 5% level and *** at 1% level.

The last four rows of Table 5.4 show the coefficients of the structural form retrieved from the estimations of the multivariate VAR model. The row OF_t shows matrix A , the off-diagonal elements, as the coefficients on the order flow (equation (5.7) $-\alpha_{1,2}$)

in the exchange rate equation. The coefficients are all significant and negative except for those in sub-period B. This indicates that order flow has a highly positive effect on exchange rate returns. In particular, in sub-period B, the effect of order flow is significant at the 1% level in the exchange rate equation. However, in sub-period B this effect seems not to be present, probably due to poor liquidity in the market. The row ER_t shows the effects of exchange rate returns in the order flow equation and is restricted to zero, because this work does not count on simultaneous feedback trading.

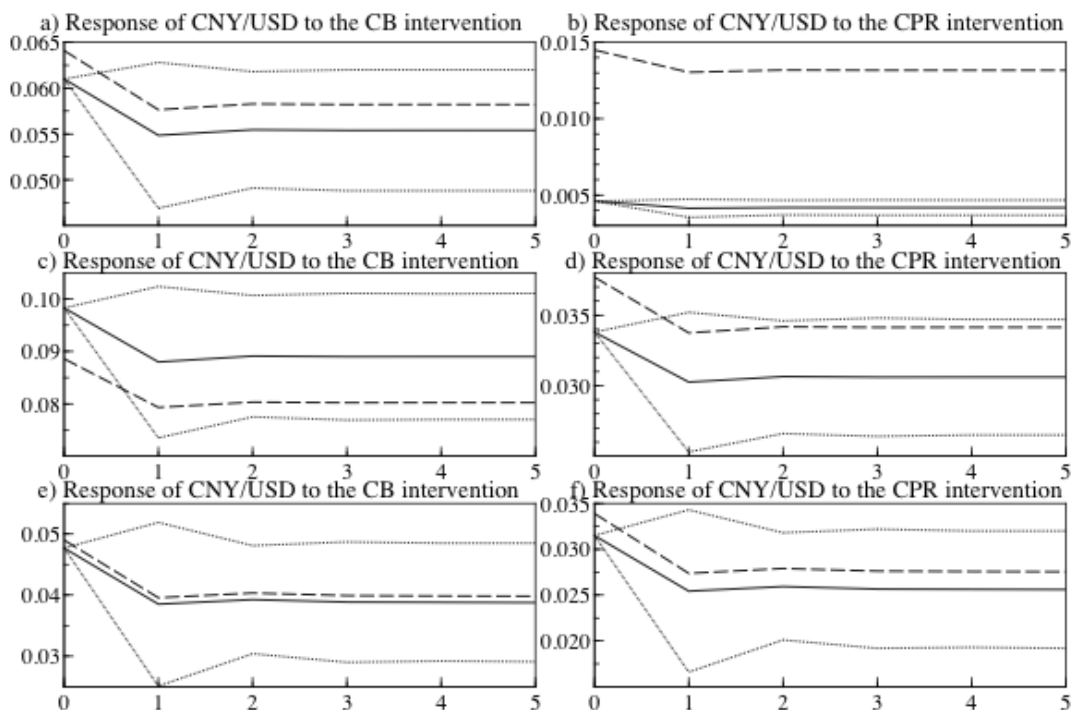
The coefficients on structural impacts of the CB and CPR interventions are shown in the final two rows respectively. Comparison of the corresponding values of the reduced form (the second row INT_t^{CB} and the third row INT_t^{CPR}) and the structural form (the last two rows $INT_t^{CB} Struck$ and $INT_t^{CPR} Struck$) reveals interesting insights. First, both the reduced and the structural forms of intervention effects have the same direction. Second, the structural form exchange rate impact of the CB intervention is slightly greater than the reduced form impact, except for sub-period A. Similarly, the structural form exchange rate impacts of the CPR interventions are greater than the reduced form impacts across all sub-periods. Third, since this research proposes no simultaneous feedback trading in our sample, there is no channel for intervention to transmit contemporaneous impact from the exchange rate to order flow. The structural coefficient in the order flow equation does not differ from that of the reduced form model. Hence, this research does not show it again in Table 5.4.

5.3.3.3 Decomposition of Intervention Impacts

In the previous section, this research show that order flow is more sensitive during intervention periods. Given that order flow presents the market reactions to CB and

CPR interventions, and has the potential to move the exchange rate, this research use a simple VAR model to estimate the intermediation effect of order flow on the exchange rate when intervention occurs. In order to evaluate to find the size of such intermediation reaction this research further explores equation (5.7) by applying restrictions on the structural coefficients on CB and CPR interventions such that impact of order flow is restricted to be zero. Consequently, all responses of the exchange rate movements can be explained as the direct impact of the intervention through the structural exchange rate equation.

Results of the impulse response function (IRF) are shown in Figure 5.3. The solid line represents the responses of the exchange rate to different interventions. The dotted line is the standard error band of the impulse response function (IRF) within the 95% confidence interval. The dashed line denotes exchange rate responses to interventions when structural coefficients on all interventions in the order flow equation are restricted to be zero. The hypothesis of exchange rate responses to interventions is that order flow has greater direct impact on the exchange rate than do the interventions themselves. The responses of the exchange rate are plotted in the following graphs:



Notes: Graphs a and b show the responses of the exchange rate to interventions in the whole sample period; graphs c and d show the responses of exchange rate to interventions in sub-period A; graphs e and f present impulse responses in sub-period B; the solid line shows impulse responses of the exchange rate to the Cholesky one S.D. intervention shocks and with the standard error bands (the dotted line); the dashed line shows the responses of the structural coefficients, to be set as zero on CB and CPR interventions in the order flow equation.

Figure 5.3 Accumulated Responses of USD/CNY Exchange Rate to Intervention

First, the influence of CB intervention on exchange rate is greater than that of CPR intervention. Second, in each graph, all the dashed lines are above the solid lines except for the CB intervention impact in sub-period A. This result indicates that the direct impact (i.e. impact not via order flow) of interventions on the exchange rate is greater than the indirect impact via order flow.

As shown before, the reduced form coefficient on CPR intervention has the wrong sign in the order flow equation, especially in sub-period B (see Table 5.4). This means that the structural form impulse responses of the exchange rate to CPR intervention through the order flow channel also have the wrong direction. Meanwhile, the impulse response of the exchange rate to CB intervention in sub-period A (Figure 5.3c) is the only normal case in our sample. In sub-period B, liquidity is poor and this also influences the whole period performance.

Table 5.5 quantifies the percentage of responses of the exchange rate to different interventions via direct impact and order flow effect. As discussed, when the coefficient on intervention in the order flow equation is wrong signed, the responses of no order flow IRF will be greater than those of reduced form IRF. The portion of the effects of intervention directly impounding into the exchange rate will be over 100% and thus the order flow ratio will be negative. This can be found in all cases except that of CB intervention in sub-period A. In these cases, order flow is wrong signed and the correct sign of reduced form coefficient is due only to the direct impact of intervention.

Table 5.5 Multivariate VAR Results of Direct and Order Flow Effects

	Whole Period		Sub-period A		Sub-period B	
	(15/12/2011-13/12/2012)		(15/12/2011-13/09/2012)		(14/09/2012-13/12/2012)	
Time Period of Shock	Direct	OrderFlow	Direct	OrderFlow	Direct	OrderFlow
	(% Share)	(% Share)	(% Share)	(% Share)	(% Share)	(% Share)
The CB Intervention						
0	105.0820	-5.0820	90.1322	9.8678	102.7254	-2.7254
1	105.0810	-5.0810	90.1326	9.8674	102.7235	-2.7235
3	105.0820	-5.0820	90.1325	9.8675	102.7253	-2.7253
5	105.0818	-5.0818	90.1327	9.8673	102.7242	-2.7242
The CPR Intervention						
0	315.2174	-215.2174	111.5385	-11.5385	107.6190	-7.6190
1	315.2321	-215.2321	111.5390	-11.5390	107.6194	-7.6194
3	315.2262	-215.2262	111.5385	-11.5385	107.6186	-7.6186
5	315.2262	-215.2262	111.5370	-11.5370	107.6217	-7.6217

Notes: The column headed 'Direct' indicates the percentage of exchange rate responses to the direct intervention upon impact; Order Flow represents the share of exchange rate responses to intervention through the order flow channel.

The share of impact of CB intervention impounded into the exchange rate via the order flow channel is relatively small. In sub-period A, it accounts for 9.8678% of the total effect contemporaneously, 9.8674% after one day, 9.8675% after three days and 9.8673% after one week (5 working days). The CB intervention impact is absorbed by the market on the day of intervention and becomes stable afterwards. Compared to the effect channelled via order flow, the share of direct impact of CB intervention is much more prominent. Turning to CPR intervention, by implication it is not meant to be used as a policy tool in actual trading activity, so its main effects are reflected in the direct impact.

5.4 Effectiveness of Chinese Intervention

Given the extensive interventions in the foreign exchange market by the Chinese authority, it is natural to ask whether these interventions are successful. In what follows, this research apply the success criteria established by Chaboud and Humpage (2005), Fatum and Hutchison (2006) and Marsh (2011) to evaluate the effectiveness of China's interventions, with necessary adaptations according to China's special institutional features.

5.4.1 Criteria of Success

1. The 'Direction' Criterion

The first criterion tested is whether the direction of the price movements is in agreement with that of the central bank intervention. For an intervention to be successful, the directional agreement is essential. This criterion can be further classified as follows:

i. The order flow movement

According to the first criterion, based on the movement of order flow in situation A, SIO_t^A , in the case that the Chinese monetary authority intervenes by purchasing the US dollar and order flow on the market also moves in the direction of dollar buying, this can be viewed as a successful intervention:

$$SIO_t^A = \begin{cases} 1 & \text{if } INT_t = 1, \text{ and } X_t > 0 \\ 0 & \text{otherwise} \end{cases}, INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases} \quad (5.8)$$

By the same criterion, based on the movement of order flow in situation B, SIO_t^B , in the case that the Chinese monetary authority intervenes to sell off the US dollar and the order flow is also out of the US dollar, this too can be viewed as an indicator of a successful intervention.

$$SIO_t^B = \begin{cases} 1 & \text{if } INT_t = -1, \text{ and } X_t < 0 \\ 0 & \text{otherwise} \end{cases}, INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases} \quad (5.9)$$

ii. The exchange rate movement

Again according to the first success criterion, based on the movement of exchange rate, when the monetary authority buys the dollar, SIB_t , if the value of the US dollar appreciates then the intervention can be deemed successful.

$$SIB_t = \begin{cases} 1 & \text{if } INT_t = 1, \text{ and } \Delta P_t > 0 \\ 0 & \text{otherwise} \end{cases}, INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases} \quad (5.10)$$

By the same criterion, based on the movement of exchange rate, when the monetary authority sells the dollar, SIS_t , if the value of the US dollar depreciates then the intervention can be said to be successful.

$$SIS_t = \begin{cases} 1 & \text{if } INT_t = -1, \text{ and } \Delta P_t < 0 \\ 0 & \text{otherwise} \end{cases}, INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases} \quad (5.11)$$

The intervention INT_t includes the CB intervention (INT_t^{CB}) and the CPR intervention (INT_t^{CPR}). ΔP_t is today's closing exchange rate minus last day's closing price.

II. The 'Reversing' Criterion

The second success criterion refers to a 'leaning against the wind' policy, whereby the Chinese central bank intervenes to reverse the current exchange rate trend.

i. The order flow movement

According to the second success criterion, based on the movement of order flow in the situation A, $SIIo_t^A$, in the case that the central bank's intervention changes the direction of order flow from out of the US dollar to into the US dollar, this can be deemed a successful intervention.

$$SIIo_t^A = \begin{cases} 1 & \text{if } INT_t = 1, \text{ and } X_t > 0 \text{ and } X_{t-1} < 0 \\ 0 & \text{otherwise} \end{cases}, \quad (5.12)$$

$$INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases}$$

Similarly, based on the movement of order flow in the situation B, $SIIo_t^B$, if the intervention changes the direction of order flow from into the dollar to out of the dollar, this can be deemed a successful intervention.

$$SIIo_t^B = \begin{cases} 1 & \text{if } INT_t = -1, \text{ and } X_t < 0 \text{ and } X_{t-1} > 0 \\ 0 & \text{otherwise} \end{cases}, \quad (5.13)$$

$$INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases}$$

ii. The exchange rate movement

Also according to the second success criterion, based on the movement of exchange rate, when the monetary authority buys or sells the dollar, $SIIb_t$ and SII_s_t , if the intervention reverses the direction of change in the dollar value, it can be deemed successful.

$$SIIb_t = \begin{cases} 1 & \text{if } INT_t = 1, \text{ and } \Delta P_t > 0 \text{ and } \Delta P_{t-1} < 0, \\ 0 & \text{otherwise} \end{cases}, \quad (5.14)$$

$$INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases}$$

$$SII_s_t = \begin{cases} 1 & \text{if } INT_t = -1, \text{ and } \Delta P_t < 0 \text{ and } \Delta P_{t-1} > 0, \\ 0 & \text{otherwise} \end{cases}, \quad (5.15)$$

$$INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases}$$

III. The 'Moderating' Criterion

This success criterion is similar to a 'leaning against the wind' policy, but rather than reverse the trend, the central bank aims to smooth and slow down the movement.

i. The order flow movement

According to the third success criterion, based on the movement of order flow in the situations A and B, $SIIIo_t^A$ and $SIIIo_t^B$, if by buying (selling) the US dollar the Chinese monetary authority slows the net order flow out of (into) the dollar, this can be deemed a successful intervention.

$$SIIIo_t^A = \begin{cases} 1 & \text{if } INT_t = 1, \text{ and } X_t > X_{t-1} \text{ and } X_t \leq 0 \text{ and } X_{t-1} < 0 \\ 0 & \text{otherwise} \end{cases}, \quad (5.16)$$

$$INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases}$$

$$SIIIo_t^B = \begin{cases} 1 & \text{if } INT_t = -1, \text{ and } X_t < X_{t-1} \text{ and } X_t \geq 0 \text{ and } X_{t-1} > 0 \\ 0 & \text{otherwise} \end{cases}, \quad (5.17)$$

$$INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases}$$

ii. The exchange rate movement

Also according to this third criterion, based on the movement of exchange rate, whenever the monetary authority buys or sells the dollar, $SIIIb_t$ and $SIII_s_t$, if the intervention declines the trend of US dollar appreciation or depreciation, it is considered to be successful.

$$SIIIb_t = \begin{cases} 1 & \text{if } INT_t = 1, \text{ and } \Delta P_t > \Delta P_{t-1} \text{ and } \Delta P_t \leq 0 \text{ and } \Delta P_{t-1} < 0 \\ 0 & \text{otherwise} \end{cases}, \quad (5.18)$$

$$INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases}$$

$$SIII_s_t = \begin{cases} 1 & \text{if } INT_t = -1, \text{ and } \Delta P_t < \Delta P_{t-1} \text{ and } \Delta P_t \geq 0 \text{ and } \Delta P_{t-1} > 0 \\ 0 & \text{otherwise} \end{cases}, \quad (5.19)$$

$$INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases}$$

IV. The 'Accentuating' Criterion

The fourth success criterion, in contrast to the second and third, follows the 'leaning with the wind' policy.

i. The order flow movement

According to the fourth success criterion, based on the movement of order flow in the situation A and B, $SIVo_t^A$ and $SIVo_t^B$, if the intervention accentuates movement of the net order flow into (out of) the US dollar, it is deemed to be successful.

$$SIVo_t^A = \begin{cases} 1 & \text{if } INT_t = 1, \text{ and } X_t > X_{t-1} \text{ and } X_{t-1} > 0, \\ 0 & \text{otherwise} \end{cases}, \quad (5.20)$$

$$INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases}$$

$$SIVo_t^B = \begin{cases} 1 & \text{if } INT_t = -1, \text{ and } X_t < X_{t-1} \text{ and } X_{t-1} < 0, \\ 0 & \text{otherwise} \end{cases}, \quad (5.21)$$

$$INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases}$$

ii. The exchange rate movement

Again according to the fourth success criterion, based on the movement of exchange rate, when the monetary authority buys or sells the dollar, $SIVb_t$ and $SIVs_t$, the intervention can be judged to be successful if it accelerates the speed of the exchange rate depreciation or appreciation.

$$SIVb_t = \begin{cases} 1 & \text{if } INT_t = 1, \text{ and } \Delta P_t > \Delta P_{t-1} \text{ and } \Delta P_{t-1} > 0, \\ 0 & \text{otherwise} \end{cases}, \quad (5.22)$$

$$INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases}$$

$$SIVs_t = \begin{cases} 1 & \text{if } INT_t = -1, \text{ and } \Delta P_t < \Delta P_{t-1} \text{ and } \Delta P_{t-1} < 0, \\ 0 & \text{otherwise} \end{cases}, \quad (5.23)$$

$$INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases}$$

V. General Criterion of Success

The final success criterion unites all the above criteria. The Chinese monetary authority intervention to purchase (sell) the USD is regarded as successful if it meets the following criteria:

- i. The intervention to purchase (sell) the US dollar is successful if it changes the order flow to into (out of) the US dollar, or at least decreases (increases) the net order flow out of (into) the US dollar.

$$SVo_t^A = \begin{cases} 1 & \text{if } INT_t = 1, \text{ and } X_t > 0 \text{ or } X_t > X_{t-1} \\ 0 & \text{otherwise} \end{cases}, INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases} \quad (5.24)$$

$$SVo_t^B = \begin{cases} 1 & \text{if } INT_t = -1, \text{ and } X_t < 0 \text{ or } X_t < X_{t-1} \\ 0 & \text{otherwise} \end{cases}, INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases} \quad (5.25)$$

- ii. Intervention to purchase (sell) the USD by the central bank of China is successful if it appreciates (depreciates) the value of the exchange rate, or at least smoothes the exchange rate movements.

$$SVb_t = \begin{cases} 1 & \text{if } INT_t = 1, \text{ and } \Delta P_t > 0 \text{ or } \Delta P_t > \Delta P_{t-1} \\ 0 & \text{otherwise} \end{cases}, \quad (5.26)$$

$$INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases}$$

$$SVs_t = \begin{cases} 1 & \text{if } INT_t = -1, \text{ and } \Delta P_t < 0 \text{ or } \Delta P_t < \Delta P_{t-1} \\ 0 & \text{otherwise} \end{cases}, \quad (5.27)$$

$$INT_t = \begin{cases} INT_t^{CB} \\ INT_t^{CPR} \end{cases}$$

5.4.2 Test Results for China

Based on the criteria given above, this research evaluate to what extent interventions by the Chinese monetary authority are successful. Table 5.6 displays the full range of Chinese foreign exchange market interventions. Tables 5.7 and 5.8 present the results of the successful CB intervention and CPR intervention respectively in the whole sample period. In each table, the columns from left to right display the total number of interventions, the number of successful interventions (as a percentage), the number of unconditional successful interventions (percentage), the number of expected successful interventions, the standard deviations (S.D.) and the probability value. To evaluate the probable number of successful interventions, this research assumes that all variables follow hypergeometric distribution. This distribution does not hinge on the presumed probability of an individual intervention being successful, and allows the individual events to be dependent. The null hypothesis is that the actual number of successful interventions is equal to the number of expected successful interventions.

Table 5.6 Summary of the Number of Chinese Interventions

Total Intervention Num.	$INT_t^{CB} = 1$		$INT_t^{CB} = -1$		$INT_t^{CPR} = 1$		$INT_t^{CPR} = -1$	
	37		90					
Whole Period (15/12/2011-13/12/2012, 243 obs.)	15	22	49	41				
Sub-period A (15/12/2011-13/09/2012, 143 obs.)	0	21	6	41				
Sub-period B (14/09/2012-13/12/2012, 60 obs.)	15	1	43	0				

Notes: The table reports the number of CB and CPR interventions in each period.

In Table 5.6, there are 37 days of CB intervention and 90 days of CPR intervention. In sub-period A, the majority of CB interventions are negative, with only one exception in which the central bank of China intervenes to sell the US dollar to accelerate the appreciation of the RMB. The fact that over 87% of the CPR interventions are negative means that the central bank of China does not want the RMB price to depreciate too much; in other words, it wishes to appreciate the RMB price against the market.

However, on 13th September 2012, the US Federal Reserve launched the third round of quantitative easing (QE3) and this, combined with a series of international events, led to massive appreciation of the RMB in the Chinese foreign exchange market, forcing the monetary authority to use the CPR intervention frequently in sub-period B to limit the RMB price within a stable range. Most of the CB interventions in sub-period B are positive.

The results of the effectiveness estimation of the Chinese intervention are demonstrated in Tables 5.7 and 5.8. While the majority of $INT_t = 1$ are in sub-period B and the majority of $INT_t = -1$ are in sub-period A, the results of SIO_t^A for the whole period could represent the performance of intervention in sub-period B, and those for SIO_t^B could represent the performance of intervention in sub-period A; the results of other success criteria are similar to those for SIO_t^A and SIO_t^B . Therefore, this work does not present the results for the separate sub-periods in this section.

Table 5.7 Number of Successful CB Interventions for Whole Sample

The CB Intervention Whole Period								
(15/12/2011-13/12/2012, 243 observations)								
	Intervention			Unconditional		Expected	Standard	P-
	Total	Success		Success		Success	Deviation	Value
	Num.	Num.	%	Num.	%	Num.	Num.	1-CDF
SIO_t^A	15	2	13.33	111	45.68	6.85	1.87	0.9923
SIO_t^B	22	11	50.00	124	51.03	11.23	2.24	0.4520
SIB_t	15	8	53.33	118	48.56	7.28	1.88	0.2586
SIS_t	22	15	68.18	120	49.38	10.86	2.24	0.0182
$SIIo_t^A$	15	1	6.67	46	18.93	2.84	1.47	0.8157
$SIIo_t^B$	22	7	31.82	47	19.34	4.26	1.77	0.0393
$SIIb_t$	15	3	20.00	59	24.28	3.64	1.61	0.5156
$SIIs_t$	22	4	18.18	60	24.69	5.43	1.93	0.6746
$SIIIo_t^A$	15	7	46.67	38	15.64	2.35	1.37	0.0005
$SIIIo_t^B$	22	2	9.09	33	13.58	2.99	1.54	0.6001
$SIIIb_t$	15	3	20.00	27	11.11	1.67	1.18	0.0701
$SIIIs_t$	22	2	9.09	28	11.52	2.54	1.43	0.4788
$SIVo_t^A$	15	0	0.00	29	11.93	1.79	1.22	0.8601
$SIVo_t^B$	22	3	13.64	35	14.40	3.17	1.57	0.3933
$SIVb_t$	15	2	13.33	31	12.76	1.91	1.25	0.2958
$SIVs_t$	22	7	31.82	33	13.58	2.99	1.54	0.0040
SVo_t^A	15	9	60.00	149	61.32	9.20	1.83	0.4418
SVo_t^B	22	13	59.09	157	64.61	14.21	2.14	0.6367
SVb_t	15	11	73.33	145	59.67	8.95	1.84	0.0797
SVs_t	22	17	77.27	148	60.91	13.40	2.19	0.0265

Notes: This table shows the successful CB interventions for the whole period. If the intervention meets any of the success criteria conditions it can be counted into the number of successful interventions. The percentage of the unconditional success is the number of days which meet the success criteria in the whole population, including intervention days and no intervention days. The probability value is observed by the hypergeometric function based on the number of conditional (unconditional) success and the whole sample size. Significant P-values and larger total success rate (compared with the unconditional success rate) are in bold type.

Table 5.7 presents the results against the success criteria for the whole sample of CB intervention. The population of the whole sample is 243, and includes 37 CB interventions. The third column gives the percentage of successful interventions under each success criterion, and the fifth shows the proportion of unconditional success based on all observations. Where the proportion of successful intervention is above that for unconditional success, this work present the result in bold.

In Table 5.7, out of 20 tests, 9 are greater than the unconditional success rates and 5 have significant probability value under 0.05, which are also marked in bold. Taking SIS_t as an example, the intervention is successful 15 times out of 22 cases and the proportion is 68.18%. This is significantly greater than the unconditional success and the probability value is 0.0182. In terms of the SIS_t , $SIVS_t$ and SVS_t success criteria, $INT_t^{CB} = -1$ indicates that the central bank intervened successfully to appreciate the RMB price by selling the US dollar during sub-period A. Similarly, $SIIo_t^B$ is strongly significant. This presents the case in which the monetary authority of China directly sells the US dollar and successfully changes the direction of order flow.

With the $SIIIo_t^A$ success criterion, $INT_t^{CB} = 1$ implies that the Chinese monetary authority purchases the US dollar and successfully slows the net order flow out of the US dollar in sub-period B. These successful CB interventions imply that, for market participants wanting to tap the Chinese foreign exchange market, they should take the general tendency of the Chinese authority's intervention into consideration when making investment decisions.

Table 5.8 provides the results of successful CPR intervention based on each success criterion for the whole sample. This includes 90 days CPR intervention and 243

observations. The percentage of successful interventions greater than the unconditional case is over 50%. However, in sub-period B only 3 tests are significant at 5% level. For the first criterion, $SIIIo_t^A$, where $INT_t^{CPR} = 1$ the CPR intervention has similar effects with the CB intervention in sub-period B. However, the process here is different.

As discussed above, in CB intervention the Chinese monetary authority purchases the US dollar to slow the net outflow of the US dollar. In contrast, CPR intervention will make the exchange rate deviate from the market expected value. More specifically, it will make the US dollar overvalued. In this case, market participants wishing to sell the US dollar would be faced with fewer buying orders as well as weaker motivations for market makers to provide liquidity. This leads to a lack of market liquidity and decreases order flow. The other two significant results in sub-period B, $SIIIb_t$ and SVb_t , both show that the CPR intervention successfully declined the trend of the US dollar appreciation and smoothed the exchange rate movements.

Table 5.8 Number of Successful CPR Interventions for the Whole Sample

The CPR Intervention Whole Period								
(15/12/2011-13/12/2012, 243 observations)								
	Intervention			Unconditional		Expected	Standard	P-Value
	Total	Success		Success		Success	Deviation	1-CDF
	Num.	Num.	%	Num.	%	Num.	Num.	
SIO_t^A	49	10	20.41	111	45.68	22.38	3.12	0.9999
SIO_t^B	41	17	41.46	124	51.03	20.92	2.92	0.8796
SIB_t	49	24	48.98	118	48.56	23.79	3.13	0.4104
SIS_t	41	22	53.66	120	49.38	20.25	2.92	0.2202
$SIIo_t^A$	49	7	14.29	46	18.93	9.28	2.46	0.7616
$SIIo_t^B$	41	9	21.95	47	19.34	7.93	2.31	0.2431
$SIIb_t$	49	14	28.57	59	24.28	11.90	2.69	0.1655
$SIIs_t$	41	9	21.95	60	24.69	10.12	2.52	0.5893
$SIIIo_t^A$	49	16	32.65	38	15.64	7.66	2.28	0.0001
$SIIIo_t^B$	41	8	19.51	33	13.58	5.57	2.00	0.0761
$SIIIb_t$	49	10	20.41	27	11.11	5.44	1.97	0.0077
$SIIIs_t$	41	3	7.32	28	11.52	4.72	1.87	0.7348
$SIVo_t^A$	49	2	4.08	29	11.93	5.85	2.03	0.9596
$SIVo_t^B$	41	3	7.32	35	14.40	5.91	2.05	0.8836
$SIVb_t$	49	3	6.12	31	12.76	6.25	2.09	0.9122
$SIVs_t$	41	7	17.07	33	13.58	5.57	2.00	0.1658
SVo_t^A	49	29	59.18	149	61.32	30.05	3.05	0.5738
SVo_t^B	41	25	60.98	157	64.61	26.49	2.80	0.6422
SVb_t	49	34	69.39	145	59.67	29.24	3.07	0.0417
SVs_t	41	25	60.98	148	60.91	24.97	2.85	0.4297

Notes: This table shows the performance of CPR intervention for the whole period in terms of the success criteria. If the intervention meets any of the success criteria, it can be counted into the number of successful interventions. The percentage of the unconditional success is the number of days which meet the success criteria in the whole population, including intervention days and no intervention days. The probability value observed by the hypergeometric function is based on the number of conditional (unconditional) success and the whole sample size. The significant P-values and the larger total success rate (compared with the unconditional success rate) are presented in bold.

5.5 Robustness of the Findings

5.5.1 The GARCH Model

In order to explore intervention effects further, including those on both the level and the volatility of exchange rate, this section apply a GARCH (1, 1) model which contains CB intervention and CPR intervention in both the mean equation and the variance equation. The specification of the models for changes in the exchange rate and order flow are formulated as follows:

$$\Delta P_t = \alpha + \beta INT_t^{CB} + \gamma INT_t^{CPR} + \varepsilon_t \quad (5.28)$$

$$\sigma_t^2 = \omega + \eta INT_t^{CB} + \theta INT_t^{CPR} + \delta \varepsilon_{t-1}^2 + \phi \sigma_{t-1}^2 + v_t$$

and,

$$X_t = \alpha + \beta INT_t^{CB} + \gamma INT_t^{CPR} + \varepsilon_t \quad (5.29)$$

$$\sigma_t^2 = \omega + \eta INT_t^{CB} + \theta INT_t^{CPR} + \delta \varepsilon_{t-1}^2 + \phi \sigma_{t-1}^2 + v_t$$

where, ε_t is the residual, σ_t^2 is the conditional variance, and variables are defined as before.

As discussed elsewhere in this chapter, the majority of CB and CPR interventions in sub-period A are negatively associated with the exchange rate returns and order flow,

while in sub-period B the majority of CB and CPR interventions are positive. The estimated coefficients on CB intervention and CPR intervention in sub-period A could represent the outcome of appreciation-targeting intervention that aims to prop up the value of domestic currency or slow the depreciation in the marketplace. CB intervention is conducted through selling the US dollar and so can be named sale intervention. For CPR intervention, the government sets a higher value of domestic currency than market expectation and limits the depreciation. The estimation results in sub-period B could represent the outcome of depreciation-targeting intervention.

5.5.2 Estimation Results of the GARCH model

Table 5.9 shows the estimation results of intervention effects on changes in the exchange rate (equation 5.28). The coefficients on interventions in the mean equation are consistent with the contemporaneous coefficients in Table 5.2. CB intervention is positively significant in both sub-periods. This is indirect evidence supporting the notion that CB intervention has the ability to appreciate RMB price by selling the US dollar in sub-period A, and reduce the appreciation of RMB price by purchase of the dollar in sub-period B. This is consistent with our finding that $SIVs_t$ is significant and $SIIIb_t$ is weak significant for CB intervention. The coefficient on CPR intervention in sub-period A is weakly significant. However, no criterion of success is significant.

In the variance equation, the estimated coefficient on CB intervention is negative and weakly significant in sub-period A and positively significant in sub-period B. This implies that CB intervention tends to reduce volatility of exchange rate growth in sub-period A and increases the volatility in sub-period B. Given the illusive nature of CB intervention on exchange rate volatility and the fact that CB intervention in China is

usually conducted by unannounced transactions, it tends to increase uncertainty, hence intensify volatility in China's foreign exchange market. In contrast, as we will see later, CPR intervention has no impact on the volatility of changes in the exchange rate.

Table 5.9 GARCH Analysis of Intervention Effects on Exchange Rate Returns

Mean Equation					
	α		β		γ
Sub-period A (15/12/2011- 13/09/2012)	0.0123 (0.0076)		0.0985*** (0.0331)		0.0216* (0.0130)
Sub-period B (14/09/2012- 13/12/2012)	-0.0733** (0.0335)		0.0662*** (0.0060)		0.0522 (0.0349)
Variance Equation					
	Ω	η	θ	δ	ϕ
Sub-period A (15/12/2011- 13/09/2012)	0.0053 (0.0037)	-0.0136* (0.0070)	0.0030 (0.0019)	0.0989 (0.1143)	0.2849 (0.3284)
Sub-period B (14/09/2012- 13/12/2012)	0.0065** (0.0026)	0.0036*** (0.0000)	-0.0040 (0.0026)	0.0000 (0.0015)	0.3276*** (0.0064)

Notes: The estimated coefficients of equation (5.28) are shown in the first row of each model. Standard errors are in the parentheses below the estimates. The significance levels are displayed as *** for 1%, ** for 5%, and *for 10%.

Table 5.10 presents the estimation results of intervention effects on order flow (equation 5.29). Again, coefficients on interventions in the mean equation are consistent with contemporaneous coefficients in Table 5.2. The coefficient on CB intervention in sub-period A is positively significant while the coefficient on CPR intervention is insignificant. This provides indirect evidence that CB intervention is able to move order flow while CPR intervention is not. This is consistent with our previous finding that $SIIo_t^B$ is significant. In sub-period B, both CB and CPR intervention are negatively significant in explaining changes in order flow. This provides some support for the finding that $SIIIo_t^A$ for both CB and CPR interventions is significant. However, both CB and CPR interventions have no impact on the volatility of order flow.

Table 5.10 GARCH Analysis of Intervention Effects on Order Flow

Mean Equation					
	A		β		γ
Sub-period A	3.3687***		7.2661**		-3.3205
(15/12/2011- 13/09/2012)	(1.2783)		(3.2431)		(2.4994)
Sub-period B	4.9026		-16.3184**		-33.6997***
(14/09/2012- 13/12/2012)	(8.3537)		(7.9648)		(8.6051)
Variance Equation					
	ω	η	θ	δ	ϕ
Sub-period A	23.7900*	-19.9958	19.1166	0.1141*	0.8017***
(15/12/2011- 13/09/2012)	(13.5900)	(29.7300)	(19.4100)	(0.0625)	(0.0801)
Sub-period B	100.0000	-79.8941	100.0000	1.0000***	0.0960
(14/09/2012- 13/12/2012)	(72.7430)	(85.5470)	(308.00)	(0.3377)	(0.1830)

Notes: The estimated coefficients in equation (5.29) are shown in the first row of each model. Standard errors are in the parentheses below the estimates. The significance levels are displayed as *** for 1%, ** for 5%, and *for 10%.

5.6 Conclusions

Despite the attention paid to China's exchange rate policy, and the growing awareness in international policy circles and academia that intervention is a central feature of that policy, little is known about China's monetary governance in relation to foreign exchange intervention and the consequences thereof. Given the intensity of the intervention, the lack of research of the issue is striking. This chapter extends the

literature on foreign exchange intervention to consider the case of China, which is perhaps the most watched emerging market in terms of its foreign exchange rate policy. This chapter concentrate on considering CB intervention and CPR intervention in China. This research first identifies the intervention days, and then moves on to empirically investigate effects of interventions on the exchange rate and order flow using a market microstructural approach. The effectiveness of Chinese intervention is assessed according to 5 sets of success criteria. To test the robustness of our empirical study, a GARCH model is applied, which also provides further examination of intervention effects on volatility.

In a reduced form of empirical model formulation, this chapter test for the effects of interventions on exchange rate movements and order flow. This research find that intervention not only impacts directly on changes in the exchange rate, but also affects the buying – selling pressure, or order flow. Intervention is more likely to occur when there are heavy selling orders with little liquidity, and where the exchange rate deviates from the central bank’s tolerable level one day before or on the same day in sub-period B of our sample data.

Sensitivity analysis sheds further light on the effects of intervention on the exchange rate returns and order flow. In sub-period A, there is positive and significant correlation between order flow and exchange rate when intervention occurs. For example, every 1% increase of net buying of the US dollar will lead to an additional 29 basis points increase of the exchange rate. This indicates that order flow carries additional information under CB intervention. This chapter also find that CPR intervention will induce order flow to show wrong signs in sub-period B.

Using a multivariate VAR model this research examine the effects of intervention on the inter-reaction between order flow and exchange rate returns. By decomposing the shocks to the intervention effects, this chapter find that the intervention directly impounded into the exchange rate plays a more prominent role than that via the order flow.

The effectiveness of Chinese intervention is assessed against 5 sets of success criteria. The results show that CB intervention can effectively influence both the exchange rate and order flow via transaction activity in sub-period A. However, due to the poor market liquidity in sub-period B, the effects of CB intervention are to provide liquidity and reduce the market transaction pressure. The CPR interventions are effective to keep the exchange rate within a stable band.

This chapter conduct a robust analysis of intervention effects in an alternative GARCH modelling framework. The results confirm the main findings of the chapter. CB intervention proves successful in moving the exchange rate and influencing order flow, but it tends to increase the volatility. With regard to CPR intervention, the Chinese central bank has been successful in using it for a 'leaning against the wind' policy. This type of intervention proves able to slow the net order flow out of the dollar, hence can smooth and slow down the order flow movement. However, it cannot reverse the trend, and it has no impact on the volatility of order flow.

Chapter 6

Chapter 6 Exchange Rate Regime Shifts in China

The aim of this chapter is to investigate the de facto exchange rate regime of the China FX market. First, this chapter detect the exact timing of the China exchange rate regime shifts. Then, this research adopt the multiple GARCH model to find the different impacts of exchange rate regime shift in the financial crisis and post-crisis periods.

Chapter 6

Exchange Rate Regime Shifts in China

6.1 Introduction

In recent decades, there have been dramatic changes to the world economy. These include rapid growth of the emerging economies and wide fluctuations of the world's major exchange rates. In response, many governments around the world have changed their policy regimes to deal with the changing economic conditions within and across countries. For example, on 21st July 2005 China announced an important change to its exchange rate policy, whereby it would adopt a managed floating rate system. This change, reiterated on 19th June 2010, represents a critical departure from China's long-held policy of pegging its currency to the US dollar. Under the new regime, the Chinese exchange rate is administered by the government but allowed to move within a fluctuation band specified by the authority (PBOC 2005, 2010).

Policy changes announced by governments are often only notional. There are frequent cases where the de jure policy changes do not necessarily mean de facto changes in the policy regime and its actual working. Furthermore, in a time of global financial crisis, shifts in government policy regimes could be further complicated by turmoil and economic chaos. All these present challenges to a sound understanding of China's new exchange rate regime.

In order to better understand the property of exchange rate regime shifts of the China FX market, this chapter adopts two different but complementary approaches, as introduced by Engel and Hamilton (1990) and by Zeileis et al. (2010), to identify and analyse China's exchange rate regime switch. In this task, the first step is to identify the timing of the regime shifts.

This chapter also attempts to acquire a better understanding of the Chinese regime-volatility puzzle from the perspective of market microstructure. Killeen et al. (2006) employ the microstructural approach to explain the different performance of the regime dependent exchange rate volatility during Europe's shift from flexible rates to fixed rates. From the microstructural perspective, the order flow plays an important role in conveying dispersed information. Following Killeen et al.'s (2006) approach, this chapter extends the literature by investigating whether adding order flow in the analysis may help solve the regime volatility puzzle in the China foreign exchange market. This thesis examines the foreign exchange pricing model, which attributes a key role to order flow.

Effects of the shifts in the Chinese exchange rate regime are intertwined with the fallout from the recent global financial crisis. In a recent empirical research, Tsangarides (2012) studies the behaviour of the emerging market governments with regard to switching their exchange rate regimes during the financial crisis and recovery periods. He finds that in the recovery periods the peg rate regimes slow the growth performance, but in the crisis periods those regimes have no differences from floating rate regimes. For the Chinese case, this chapter employ the DCC AR (1)-GJR (1, 1) model to analyse the dynamic regime performance across the financial crisis in terms of the bid-ask exchange rate spread. Moreover, this chapter also investigate to

what extent FX intervention by the Chinese government changes, or becomes more likely to occur, during the periods under examination.

This chapter further explore the economic significance of the RMB exchange rate exposure introduced by the freedom, though moderate, of rate changes afforded by the new exchange rate regime. This chapter apply the AR (1)-GJR (1, 1) model to investigate the economic significance of the exchange rate fluctuations across the financial crisis periods.

This chapter find that both regime detecting methods identify 21st June 2010 as the date of regime shift of the China FX market. The period before this date is characterised by the significant influence of the global financial crisis, during which volatility of the RMB exchange rate has low variance. After this date, the world begins to see some easing of the crisis. The Chinese monetary authority then starts to allow greater RMB exchange rate flexibility, and consequently volatility of the trade-weighted RMB real exchange rate increases. In the periods under examination, the U.S. dollar maintains its dominant weight in the reference currency basket, but there is significant evidence that the Chinese exchange rate no longer pegs only to the dollar.

For the regime volatility puzzle and the role of order flow in the process, this chapter find evidence that appreciation of the RMB exchange rate is order flow driven during the post-crisis period. During the crisis period, deviations from the central parity rate (CPR) increase the possibility of government intervention, and the intervention correlates with bid-ask exchange rate spread. The Chinese monetary authority is found to act to keep the exchange rate stable. In the post-crisis period, the correlation

becomes time-varying and the government prefers the RMB exchange rate to gradually appreciate.

There is a significant negative currency exposure during the financial crisis, caused by changes in the RMB exchange rate, indicating that the Chinese stock market exhibits a negative reaction in the period. However, no significant impact is found in the post-crisis period. In order to modify the exchange rate exposure to fluctuations of the U.S. dollar, the Chinese government seems to have adopted the relatively more efficient exchange rate regime to handle the effects of the global financial crisis (Zhang et al., 2011).

The research presented in this chapter makes three main contributions to the literature. First, this chapter have amassed a large data set that covers the period from 22nd July 2005, when the Chinese government adopted a managed floating exchange rate regime, until 9th October 2012. This sample size can help us detect the de facto exchange rate regime of China after the monetary authority adopted the managed floating rate arrangement. Second, the study uses the market microstructural approach to analyse the tick-by-tick transaction price in order to examine China's government intervention across the global financial crisis. Third, this research employs the multiple GARCH model to analyse the impact of China's exchange rate regime shift during the period under examination.

The rest of the chapter is organised as follows. The following Section contains the data description. Section three presents the adopted models and discusses the findings. Section four concludes.

6.2 Data

This chapter examines the different performance of Chinese foreign exchange regimes. The data deployed are in four main parts. The first part comprises the daily central parity rate (CPR) and the daily market exchange rate. The second sector includes the daily closing price of the USD/CNY exchange rate, the daily order flow, and the daily overnight interest rate differential. The third part contains the midday bid-ask spreads, the midday positive deviations from the CPR (PDC), the midday negative deviations from the CPR (NDC), and the midday order flow. The final part embraces the daily MSCI (Morgan Stanley Capital International) China index, the daily MSCI world index and the daily one-month Eurodollar rate. Only the first sample of the data, the CPR and the market exchange rate, spans the period from 22nd June 2005 to 9th October 2012.³⁸ Due to data availability, all other data samples run from 9th Dec 2009 to 9th Oct 2012 exclusive of holidays.³⁹

The period overlaps with the U.S. subprime crisis. Celik (2012) finds that during that crisis financial markets suffered from the financial contagion effect, with the emerging markets experiencing the most severe impacts. Figure 6.1 shows the movements of three major currencies and the renminbi against the U.S. dollar during the financial crisis. This research finds that values of the three major currencies appreciated, because the dollar depreciated during the subprime crisis period. It is noteworthy that movements of the RMB exchange rate (Fig.6-1d: USD/CNY) diminish, and become almost a straight line from mid-2008 to mid-2010, suggesting

³⁸ On 21st June 2005, at 19:00 (non-trading hours), the transaction price of the USD/CNY exchange rate was adjusted to 8.1100 Yuan, as the CPR price of the next day's interbank market transaction price. Since then, the Chinese central bank has published the CPR price every working day.

³⁹ Excluding public holidays of China and the United States.

that during the crisis the Chinese currency changed to an almost fixed exchange rate regime.

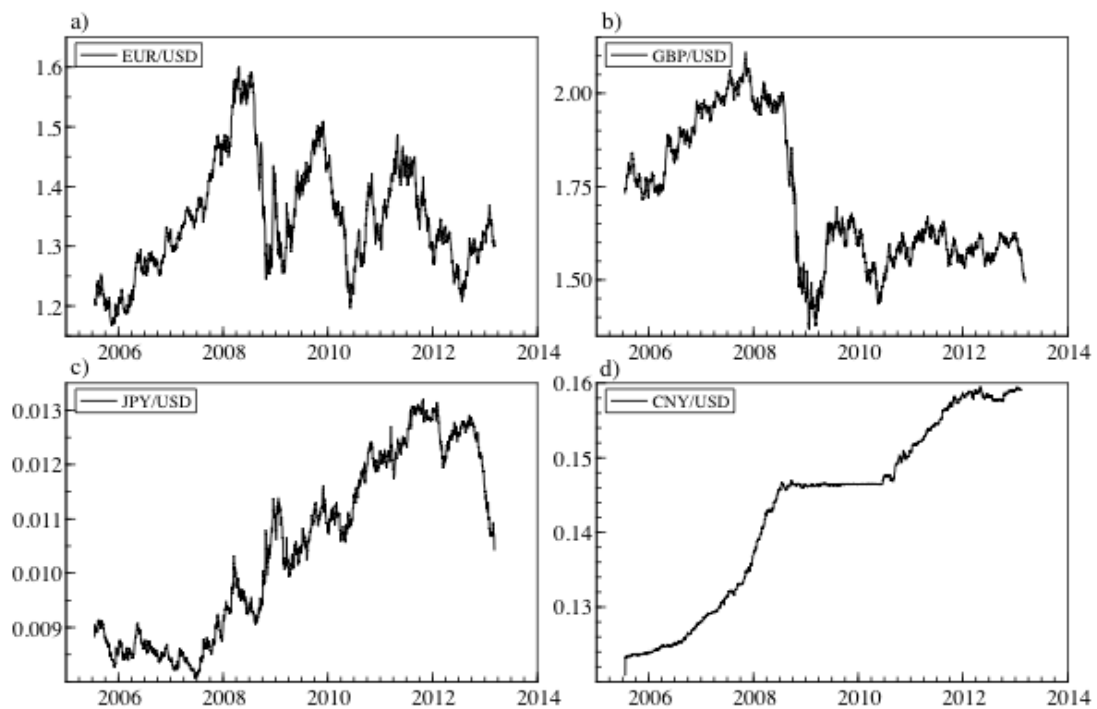


Figure 6.1 Daily exchange rate movements, a: Euro, b: Great Britain, c: Japan, d: China

As a first step, in order to identify regime shifts in China's exchange rate arrangements, this research deploy the CPR and the market exchange rate price. The daily central parity rate, used in this study as the benchmark for transaction price of USD/CNY, is published by the China Foreign Exchange Trade System (CFETS) on

every working day before the market opens.⁴⁰ Every morning, the CFETS collects every market maker's preferred price and calculates the weighted average price, excluding the highest and lowest price, as the intraday CPR of USD/CNY. The weight used for averaging is based on every member's previous transaction records in terms of transaction volumes and the bid/ask price. The CPR prices of other currencies are obtained from the cross rates between the renminbi against the USD and other major currencies as quoted in the international foreign exchange markets at 9 a.m.⁴¹

In setting the CPR, the People's Bank of China is guided by the aim to keep the RMB exchange rate stable by keeping it in a stable horizontal band. In the IMF annual report (IMF 2012), the de facto exchange rate regime of China is described as a 'crawl-like arrangement'. Prior to 21st May 2007, fluctuation of the USD/CNY transaction price in the interbank market was controlled by the government, so that the price remained within a narrow band around $\pm 0.3\%$ of the daily CPR. After that date, the monetary authority extended the band to $\pm 0.5\%$. On 16th April 2012, the State Administration of Foreign Exchange (SAFE) announced the widening of the maximum fluctuation of USD/CNY bid and ask price from 1% to 2% around the CPR. The CPR data are from the CFETS official website and Wind Info.⁴²

In order to better understand China's regime changes this research explore the differences between the policy driven exchange rate (CPR) and the actual exchange rate on the exchange market in China. Historical data of the daily market exchange

⁴⁰ Details of the central parity rate are from the CFETS official website: <http://www.chinamoney.com.cn/fe/Channel/2781516>, last accessed on 10 May 2013.

⁴¹ Currently, the PBOC as the central bank authorises the CFETS to release information only about the direct trading data of 100JPY/CNY, CNY/MYR and CNY/RUB. The exchange rates of the RMB against other currencies are obtained on the basis of the USD/CNY rate.

⁴² Shanghai Wind Information Co., Ltd. <http://www.wind.com.cn>, last accessed on February 2013.

rate are obtained from the Pacific Exchange Rate Service at the UBC.⁴³ This chapter obtain the RMB exchange rates against six major currencies: CAD, CNY, USD, EUR, GBP, and JPY. The time periods for our sample are all from 22nd Jul 2005 to 9th Oct 2012.

In order to calculate the daily order flow, this research use the intraday tick-by-tick USD/CNY transaction price from China's interbank spot foreign exchange market. All intraday tick-by-tick USD/CNY transaction prices, and the daily closing prices of USD/CNY, are obtained from the Reuters 3000 Xtra, one of the largest licensed data vendors of the CFETS.

In the microstructural approach, order flow plays an important role in conveying dispersed information. As explained previously, order flow is calculated as the difference between the buyer initiated and seller initiated trades. Following Evans (2011), this thesis apply the 'Lee and Ready' trade identification method to estimate the daily order flow of the USD/CNY transaction from every tick transaction price. The daily overnight interest rate differential is the difference between the Shibor (domestic) overnight interest rate and the U.S. (foreign) overnight interest rate, collected from DataStream. The time period is from 9th Dec 2009 to 9th Oct 2012.

To examine the relation between exchange rate spreads and market possibility intervention across the global financial crisis, this chapter employ the data of midday bid-ask spreads, midday Positive Deviations from the CPR (PDC), midday Negative Deviations from the CPR (NDC), and the midday order flow. The midday bid-ask

⁴³ The Pacific Exchange Rate Service is managed by Professor Werner Antweiler of the University of British Columbia Sauder School of Business, <http://fx.sauder.ubc.ca>, last accessed on 16 April 2013.

spread is defined as the ask price minus the bid price at the end of the midday interval. If the transaction price at the end of midday minus the CPR is positive this research defines it as PDC, otherwise it is defined as NDC. The method of calculating the midday order flow is similar to that for calculating the daily order flow, in that it is accumulated at the end of every midday interval.

To estimate whether the currency exposure in China is economically significant during the exchange rate regime shift, this chapter collates the data of the daily MSCI China index, the daily MSCI emerging market index and the daily one-month Eurodollar from 9th Dec 2009 to 9th Oct 2012, all obtained from DataStream as provided by Morgan Stanley Capital International. Table 6.1 shows the descriptive statistics of the data. The higher kurtosis of Panel C shows that the level data might not follow the normal distribution. This chapter adopts the DCC-GARCH model to account for possible effects of outliers.

Table 6.1 Descriptive Statistics

	Mean	SD	Skewness	Kurtosis	J-B	Obs.
Panel A: 2005/07/22 – 2012/10/09						
CPR	6.5495	0.4417	1.2946	3.0357	1121***	1690
Market Exchange Rate						
CAD	0.9946	0.0881	0.3892	-0.1020	43.40***	1690
CNY	6.5506	0.4416	1.2810	2.9682	1083***	1960
USD	0.9344	0.1220	0.5913	-0.2674	103.5***	1960
EUR	0.6932	0.0827	0.8049	-0.7587	223.0***	1960
GBP	0.5523	0.1091	0.1415	-1.3343	131.0***	1960
JPY	90.423	6.5326	0.1621	-0.9345	68.90***	1960
Panel B: 2009/12/09 – 2012/10/09						
Closing Price						
of USD/CNY	6.5458	0.1978	0.2670	-1.5092	68.98***	646
Daily Order						
Flow	-16.77	24.863	-0.6201	0.2911	43.69***	646
Interest Rate						
Differential	3.0808	0.4287	0.2673	19.114	9826***	645
Panel C: 2009/12/09 T12: 30 – 2012/10/09 T15: 30						
Bid-ask						
Spreads	0.0759	0.1049	8.4162	115.23	775190***	1372
PDC						
NDC	0.7065	1.3193	2.1977	4.1947	2110.3***	1372
Midday Order						
Flow	-8.5545	15.387	-0.7364	0.7631	157.29	1372
Panel D: 2009/12/09 – 2012/10/09, Source: DataStream.						
MSCI China						
Index	92.054	7.5117	-0.0135	-0.5807	10.419***	740
Emerging						
Market Index	1849.4	153.96	0.1939	-1.0175	36.558***	740
Eurodollar						
Rate	0.3196	0.0486	0.4736	1.0559	62.042***	740

Note: The significance levels are displayed as *** for 1%, ** for 5%, and * for 10%. In Panel A, all the currencies are level data, with the CHF (the Swiss franc) used as the numeraire. *Source:* CFETS, Wind Info and Pacific Exchange Rate Services, unless otherwise specified.

6.3 Empirical Findings and Analysis

To facilitate investigation of the behaviour of the renminbi exchange rates across the global financial crisis, this research divide this section into two parts. In the first part, this research apply the Markov switching model and also follow the approach of Zeileis et al. (2010) to identify the dates of the de facto exchange rate regime shifts in China. In the second part, this research adopts the multiple GARCH model to examine the impacts of China's regime shifts in different periods across the global financial crisis.

6.3.1 Identifying Regime Shifts in China's Exchange Rates

This section applies two complementary methods to analyse exchange rate regime shifts in China. The approaches introduced by Engel and Hamilton (1990) and by Zeileis et al. (2010) are deployed to analyse the patterns of renminbi exchange rate changes in order to determine the dates of the Chinese regime shifts.

6.3.1.1 The Markov Switching Model

Following Engel and Hamilton (1990), a regime switching regression can be described as follows:

$$y_t = \begin{cases} \mu_0 + \beta_1 y_{t-1} + \varepsilon_t, & \text{if } s_t = 0 \\ \mu_1 + \beta_2 y_{t-1} + \varepsilon_t, & \text{if } s_t = 1 \end{cases} \quad (6.1)$$

where, $\varepsilon_t \sim N[0, \sigma^2]$ is the residual which follows normal distribution; y_t denotes the change data of the exchange rate time series; s_t is an unobserved random variable

and denotes the exchange rate regime. The mean can be written as a function in the form: $\mu(s_t) = \begin{cases} \mu_0 & \text{if } s_t = 0 \\ \mu_1 & \text{if } s_t = 1 \end{cases}$; β_i is a vector of parameters; ε_t follows the Gaussian white noise. In this Markov switching model, the unobserved random variable s_t is assumed to follow the first-order Markov chain, defined by the ergodic transition probabilities between the states i and j :

$$p_{ij} = P[s_{t+1} = i | s_t = j] \quad (6.2)$$

where the ergodic transition probabilities p_{ij} can be characterised by the following matrix, if there are two regimes:

$$P = (p_{ij}); \text{ or } P = \left(\begin{array}{c|cc} & s_t = 0 & s_t = 1 \\ \hline s_{t+1} = 0 & p_{11} & 1 - p_{22} \\ s_{t+1} = 1 & 1 - p_{11} & p_{22} \\ \Sigma & 1 & 1 \end{array} \right) \quad (6.3)$$

6.3.1.1.1 Regime Shifts in the Policy Driven Exchange Rate – the CPR

Detection of the exact timing of exchange rate regime switching in China has a unique dimension, since the CPR is a policy driven price.⁴⁴ Here this work use Engel and Hamilton's (1990) approach to analyse possible regime shifts according to the CPR data. Table 6.2 and Figure 6.2 show the empirical results from the two-regime MS model.

⁴⁴The reason for this is explained in the data section.

Table 6.2 Estimation results with Markov Switching Model for CPR 2005/07/22-
2012/10/09

Markov Model Parameters						
	μ_0	μ_1	σ_0	σ_1	p_{11}	p_{22}
CPR_t	-0.0221***	-0.0021**	0.1187***	0.0211***	0.9913***	0.9825***
	(0.0035)	(0.0009)	(0.0025)	(0.0008)	(0.0034)	(0.0065)
Regime Classification						
Regime 0	Days	Avg. Prob.	Regime 1	Days	Avg. Prob.	
2005-07-22 - 2005-07-22	1	1.000	2005-07-25 - 2006-03-13	152	0.983	
2006-03-14 - 2006-06-27	71	0.965	2006-06-28 - 2006-07-17	14	0.936	
2006-07-18 - 2007-06-13	219	0.974	2007-06-14 - 2007-06-29	12	0.872	
2007-07-02 - 2008-10-07	310	0.998	2008-10-08 - 2008-11-27	37	0.913	
2008-11-28 - 2008-12-02	3	0.854	2008-12-03 - 2008-12-16	10	0.880	
2008-12-17 - 2008-12-19	3	0.896	2008-12-22 - 2010-06-21	363	0.997	
2010-06-22 - 2011-01-14	139	0.996	2011-01-17 - 2011-01-27	9	0.951	
2011-01-28 - 2012-10-09	410	0.986				

Notes: The dependent variable CPR_t is the change in the 100-log difference of the CPR price. The standard errors are shown below the estimates. The significance levels are displayed as *** for 1%, ** for 5%, and *for 10%.

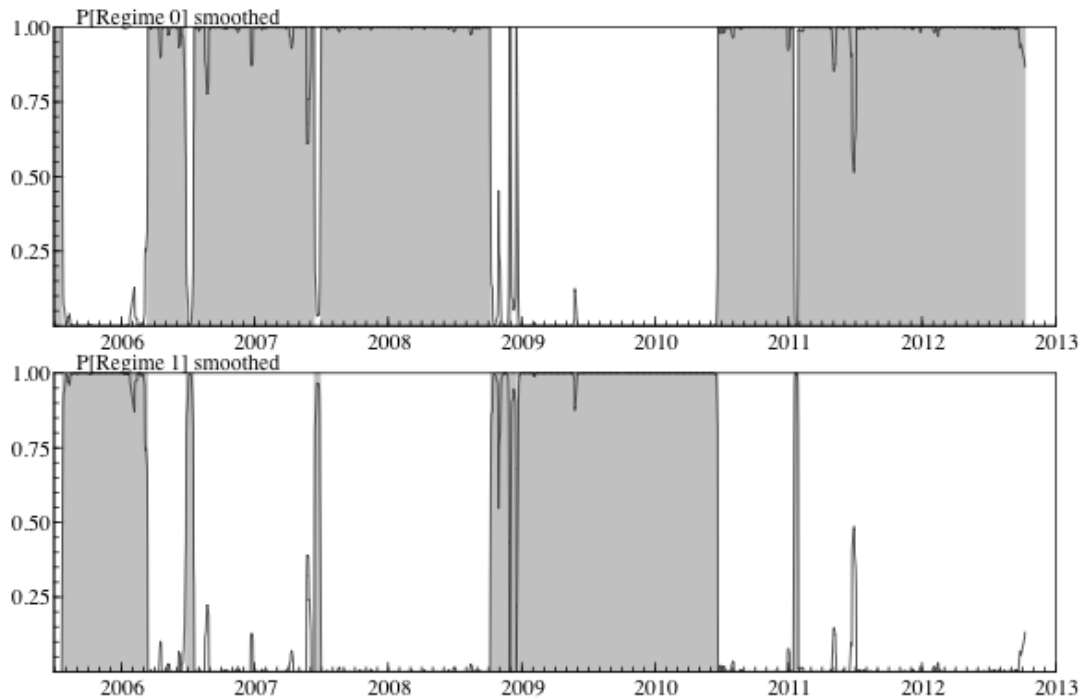


Figure 6.2 Smoothed probabilities of two regimes for CPR

July 2005 – December 2012

From Table 6.2, this section finds that the variances of the two regimes are asymmetric. Regime 0 has high variance, while regime 1 has low variance. Meanwhile, both regimes' μ are significantly negative and different from zero. This means that the Chinese renminbi (RMB) has a long-term appreciation trend during the period under examination, i.e. from 22nd July 2005 to 9th October 2012. The transition probabilities are also highly significant. For regime 1 the CPR is relatively stable, especially from 22nd December 2008 to 21st June 2010, when the Chinese economy was facing the high impact of the global financial crisis.

The estimation result for this crisis period indicates that changes in the CPR price have very low variance and relatively slow appreciation, reflecting part of China's handling of the fallout of the global financial crisis.

From the results, it can be seen that after 21st June 2010, the Chinese government seems to have decided to further reform the RMB exchange rate formation mechanism. Consequently, the RMB exchange rate flexibility is enhanced. The reform focuses on allowing for a greater role of market supply and demand in determining the RMB exchange rate. In our sample estimation, the identified regime 1 covers the period from 22nd June 2010 to 2011, which is the immediate post-crisis period. As indicated in Table 6.2, in regime 0 the variances (appreciation speed) of the CPR price are nearly 5 times (9 times) higher than for regime 1.

Meanwhile, in Figure 6.2, the MS model identifies 6 periods of low variance and slow appreciation process for regime 1, presented as grey areas in the figure. The longest period begins around the end of 2008 and continues until 21st June 2010, which corresponds to the period when the global financial crisis was hitting China with greatest force. This indicates that while movements of the policy driven CPR price were kept stable as part of the Chinese strategy to deal with the consequences of the global financial crisis, once the crisis had passed its height (at least in China), China resumed the momentum of the exchange reform by allowing more room for the CPR price to have greater flexibility.

6.3.1.1.2 Regime Shifts in the Market Exchange Rate

This section now deploy the historical data of market exchange rate to estimate the two-regime MS model as a further exercise for dating and analysing China's regime switching. This will allow for comparison analysis of regime shifts in the two different types of data, i.e. the policy driven CPR price and the market driven exchange rate. Table 6.3 and Figure 6.3 display the results of the two-regime MS model with the daily USD/CNY historical data.

From Table 6.3, both regimes' μ are significant and negative. In common with the performance of CPR, the market traded USD/CNY exchange rates also have a long-term appreciation trend from 22nd June 2005 to 9th October 2012. The variances of the actual market USD/CNY exchange rate price are higher than those of the CPR in both regimes. This indicates that the actual market USD/CNY exchange rate prices are more fluctuating. The high variance is still found in regime 0, while the low variance is a feature of regime 1. The results for regime 0 indicate that the appreciation speed (variance) of the market USD/CNY exchange rate price is over 8 times (3 times) higher than that for regime 1.

Meanwhile, in Figure 6.3, the MS model identifies some periods of low variance and slow appreciation process for regime 1, presented as grey areas. The longest period begins around 24th March 2009 and lasts until 17th June 2010, which corresponds to the financial crisis period. Similarly, during the crisis period the market USD/CNY exchange rate under regime 0 is more stable, but in the post-crisis period it becomes more flexible.

Table 6.3 Estimation results with Markov Switching Model for USD/CNY,
2005/07/22-2012/10/09

Markov Model Parameters						
	μ_0	μ_1	σ_0	σ_1	p_{11}	p_{22}
USD/CNY	-0.0231*** (0.0043)	-0.0030** (0.0015)	0.1342*** (0.0037)	0.0391*** (0.0018)	0.9408*** (0.0135)	0.9287*** (0.0145)

Regime Classification					
Regime 0	Days	Avg. Prob.	Regime 1	Days	Avg. Prob.
2005-09-06 - 2005-09-06	1	1.000	2005-07-22 - 2005-09-02	30	0.953
2005-10-12 - 2005-10-17	4	0.742	2005-09-07 - 2005-10-11	24	0.945
2005-11-01 - 2005-11-22	15	0.841	2005-10-18 - 2005-10-31	10	0.773
2006-03-15 - 2006-03-15	1	0.514	2005-11-23 - 2006-03-14	77	0.905
2006-04-13 - 2006-04-19	4	0.592	2006-03-16 - 2006-04-12	20	0.756
2006-05-30 - 2006-06-20	16	0.891	2006-04-20 - 2006-05-29	27	0.932
2006-07-07 - 2006-07-07	1	0.522	2006-06-21 - 2006-07-06	11	0.916
2006-07-20 - 2006-09-13	38	0.859	2006-07-10 - 2006-07-19	8	0.790
2006-09-18 - 2006-09-27	8	0.891	2006-09-14 - 2006-09-15	2	0.569
2006-10-11 - 2006-10-17	5	0.898	2006-09-28 - 2006-10-10	8	0.773
2006-10-25 - 2006-10-30	4	0.884	2006-10-18 - 2006-10-24	5	0.617
2006-11-24 - 2006-12-08	11	0.729	2006-10-31 - 2006-11-23	17	0.898
2006-12-28 - 2007-02-12	32	0.917	2006-12-11 - 2006-12-27	11	0.787
2007-02-27 - 2007-02-27	1	0.607	2007-02-13 - 2007-02-26	10	0.885
2007-03-02 - 2007-03-09	6	0.613	2007-02-28 - 2007-03-01	2	0.505
2007-03-15 - 2007-03-19	3	0.684	2007-03-12 - 2007-03-14	3	0.576
2007-04-05 - 2007-04-11	4	0.938	2007-03-20 - 2007-04-04	12	0.767
2007-04-20 - 2007-04-30	7	0.880	2007-04-12 - 2007-04-19	6	0.706
2007-05-08 - 2007-09-25	97	0.898	2007-05-01 - 2007-05-07	5	0.699
2007-10-09 - 2008-02-06	83	0.948	2007-09-26 - 2007-10-05	8	0.869
2008-02-11 - 2008-04-29	56	0.951	2008-02-07 - 2008-02-08	2	0.532
2008-05-08 - 2008-09-29	99	0.963	2008-04-30 - 2008-05-07	6	0.776
2008-10-06 - 2008-10-10	5	0.902	2008-09-30 - 2008-10-03	4	0.689
2008-10-24 - 2008-10-29	4	0.916	2008-10-14 - 2008-10-23	8	0.761
2008-11-26 - 2009-01-08	29	0.937	2008-10-30 - 2008-11-25	18	0.716
2009-02-02 - 2009-02-17	12	0.964	2009-01-09 - 2009-01-30	16	0.948
2009-03-19 - 2009-03-23	3	0.895	2009-02-18 - 2009-03-18	21	0.904
2010-06-18 - 2010-07-06	12	0.940	2009-03-24 - 2010-06-17	311	0.986
2010-08-10 - 2010-08-24	11	0.872	2010-07-07 - 2010-08-09	23	0.933
2010-08-31 - 2010-09-27	19	0.929	2010-08-25 - 2010-08-30	4	0.663
2010-10-08 - 2011-01-18	68	0.976	2010-09-28 - 2010-10-07	8	0.772
2011-01-31 - 2011-02-23	18	0.972	2011-01-19 - 2011-01-28	8	0.852
2011-03-04 - 2011-04-11	27	0.917	2011-02-24 - 2011-03-03	6	0.784
2011-04-21 - 2011-04-29	6	0.996	2011-04-12 - 2011-04-20	7	0.690
2011-05-12 - 2011-06-29	34	0.932	2011-05-02 - 2011-05-11	8	0.870
2011-07-12 - 2011-12-05	101	0.939	2011-06-30 - 2011-07-11	7	0.681
2011-12-14 - 2012-01-20	25	0.965	2011-12-06 - 2011-12-13	6	0.767
2012-01-31 - 2012-02-08	7	0.971	2012-01-23 - 2012-01-30	6	0.787
2012-02-27 - 2012-03-16	15	0.839	2012-02-09 - 2012-02-24	12	0.880
2012-03-21 - 2012-04-17	19	0.853	2012-03-19 - 2012-03-20	2	0.511
2012-05-10 - 2012-06-08	21	0.929	2012-04-18 - 2012-05-09	16	0.871
2012-06-15 - 2012-08-20	45	0.893	2012-06-11 - 2012-06-14	4	0.635
2012-09-11 - 2012-09-28	14	0.936	2012-08-21 - 2012-09-10	14	0.871
			2012-10-01 - 2012-10-09	6	0.833

Notes: The dependent variable USD/CNY is the change in the 100-log difference of the historical exchange rates of the renminbi against the dollar. The standard errors are shown below the estimates. The significance levels are displayed as *** for 1%, ** for 5%, and *for 10%. **Source:** Pacific Exchange Rate Service at UBC.

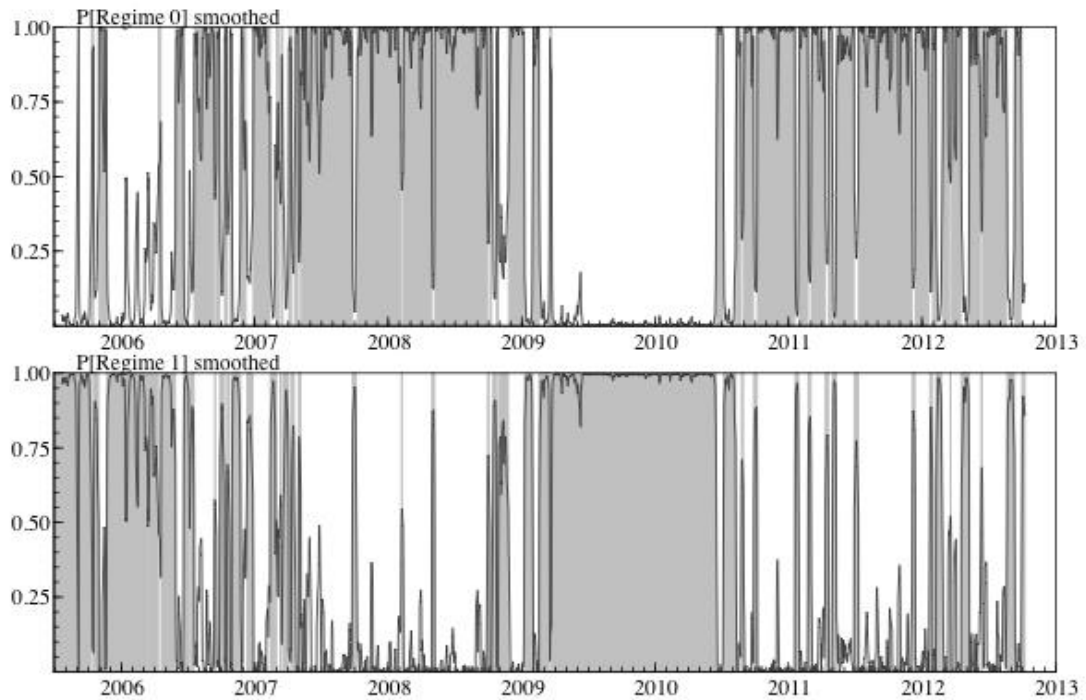


Figure 6.3 Smoothed probabilities of two regimes for USD/CNY

July 2005 – December 2012

6.3.1.2 Changes to the Currency Basket Composition

The currency reference basket is a central feature of the new Chinese exchange rate arrangement (Zhang, Shi, and Zhang 2011). Instead of focusing on model parameters, this section measures the regime shift in currency weights in the reference basket. If there is a fundamental change to the currency composition of the reference basket, that can be interpreted as a regime shift.

For our research investigation, this research begin with the question: To what extent does the Chinese government adopt a managed floating RMB exchange rate regime based on the market supply and demand with reference to a basket of currencies? To find the answer, this research use the approach developed by Zeileis et al. (2010) to

explore the behaviour of China's de facto foreign exchange regime shifts. Here, this section follow Ciubotaru (2011) to estimate the CNY (Chinese Yuan) exchange rate regime:

$$y_t = \beta_0 + \sum_{i=1}^n \beta_i x_t + \epsilon_t \quad (6.4)$$

where y_t is the log return of the CNY/CHF; β_0 is the average rate of RMB depreciation; x_t is the potential currency in the reference basket; β_i are the weights of these reference basket currencies. There are three possible situations: First, if β_0 is different from zero, this can be described as a crawling peg exchange rate policy. Second, if one of the coefficients of β_i is different from the unity, this indicates a peg to one currency. Third, if no β is significantly different from zero, the CNY is following a floating exchange rate regime.

This research select for the potential reference basket the currencies whose issuing countries are major trade partners of China. This means our selection comprises CAD, CNY, USD, EUR, GBP, and JPY. All data of the currencies are transformed to use the CHF (the Swiss franc) as the numeraire. Following equation (6.4), the regression equation can be formulated as follows:

$$\begin{aligned} d\log \frac{CNY}{CHF} = & \beta_0 + \beta_1 d\log \frac{CAD}{CHF} + \beta_2 d\log \frac{USD}{CHF} \\ & + \beta_3 d\log \frac{EUR}{CHF} + \beta_4 d\log \frac{GBP}{CHF} + \beta_5 d\log \frac{JPY}{CHF} + \epsilon_t \end{aligned} \quad (6.5)$$

6.3.1.2.1 Policy Driven Exchange Rate – the CPR

This section first follows equation (6.5) to detect regime changes in China's currency basket based on the policy exchange rate, i.e. the CPR. Table 6.4 and Figure 6.4 display the empirical results with the policy driven exchange rate using the approach of Zeileis et al. (2010). To begin with, this research set the optimal breakpoints from 1 to 10 breaks with 20 observations as the minimal segment size. The NLL (Negative Log-Likelihood) and LWZ criteria are shown in Figure 6.4.⁴⁵ The smallest LWZ indicates that the optimal number of breakpoints is 4.

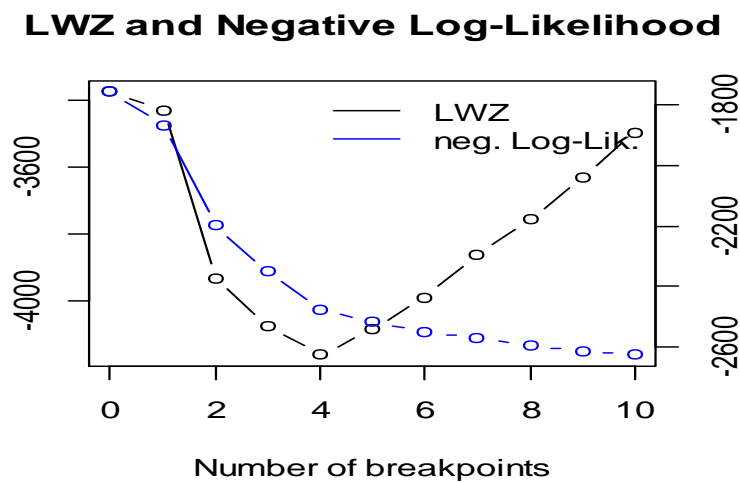


Figure 6.4 Number of breakpoints for the CPR exchange rate regimes

July 2005 – December 2012

⁴⁵LWZ is the information criterion for model selection. Its penalty is higher than the BIC. For details see (Bai and Perron 2003).

Table 6.4 Segmented CPR exchange rate regimes

2005/07/22-2012/10/09

Periods	1	2	3	4	5
Start/End	2005/07/21 2006/03/14	2006/03/15 2008/12/01	2008/12/02 2009/10/09	2009/10/13 2010/06/21	2010/06/22 2012/10/09
β_0	-0.0049** (0.0023)	-0.0251*** (0.0040)	-0.0011 (0.0017)	-0.00007 (0.0004)	-0.0136*** (0.0044)
β_{USD}	1.0029*** (0.0059)	0.9818*** (0.0100)	0.9923*** (0.0027)	0.9980*** (0.0009)	0.9721*** (0.0116)
β_{JPY}	0.0014 (0.0053)	-0.0028 (0.0082)	0.0018 (0.0021)	0.0004 (0.0006)	-0.0039 (0.0081)
β_{EUR}	-0.0265 (0.0170)	0.0102 (0.0173)	0.0054 (0.0050)	0.0014 (0.0012)	0.0180* (0.0101)
β_{GBP}	-0.0003 (0.0080)	0.0067 (0.0092)	-0.0025 (0.0021)	0.0010 (0.0007)	0.0199* (0.0112)
β_{CAD}	0.0081 (0.0055)	-0.0115 (0.0073)	0.00004 (0.0023)	0.0004 (0.0006)	0.0009 (0.0092)
σ	0.0278	0.1007	0.0242	0.0047	0.1007
R^2	0.9981	0.9770	0.9995	1	0.9860

Notes: The dependent variable CNY/CHF is the change in the log difference of the CPR price. The standard errors are shown below the estimates. The significance levels are displayed as *** for 1%, ** for 5%, and *for 10%.

The four optimal breakpoints segmenting the five periods are displayed in Table 6.4. The coefficient β stands for the weights of potential anchor currencies. All these results show that the CPR price is pegged to the U.S. dollar all the time, even after the

reform of 22nd July 2005, albeit with varying degrees of peg in different periods. Sometimes the peg is tight, while at others it is relaxed slightly and allows for some margins. The R^2 is another indicator of the margins of fluctuation.

In particular, in period 4, from 13th October 2009 to 21st June 2010, the U.S. dollar is highly significant, with a weight of 0.9938, and the R^2 reaches 1. This clearly indicates that the CPR price is tightly pegged to the U.S. dollar, especially during the financial crisis period. But in the post-crisis period, from 22nd June 2010 to 9th October 2012, the RMB regime slightly relaxes.

There are two coefficients of the potential anchor currencies that are significantly different from zero. The euro, with a weight of 0.0180 in the reference basket, and the British pound, with a weight of 0.0199, are significant at 10% level. It is plausible that this reveals a policy preference of the Chinese monetary authority in forming the composition of the currency reference basket.

6.3.1.2.2 The Market Exchange Rates

Now, this section takes the historical data of the market exchange rates to measure the basket weights. Table 6.5 and Figure 6.5 display the empirical results of the segmented USD/CNY exchange rate regimes. From Figure 6.5, the smallest number of LWZ is three. Thus, there are three optimal breakpoints, and the LWZ is segmented into four periods.

LWZ and Negative Log-Likelihood

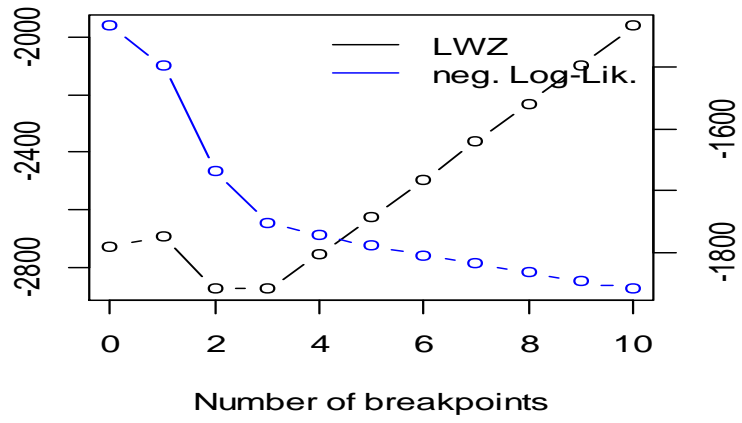


Figure 6.5 Number of breakpoints for the RMB exchange rate regimes

July 2005 – December 2012

Table 6.5 The segmented RMB exchange rate regimes, 2005/07/22-2012/10/09

Periods	1	2	3	4
Start/End	2005/07/22 2007/04/27	2007/04/30 2009/02/17	2009/02/18 2010/06/11	2010/06/17 2012/10/09
β_0	-0.0119*** (0.0035)	-0.0297*** (0.0064)	0.00007 (0.0020)	-0.0152*** (0.0054)
β_{USD}	0.9822*** (0.0097)	0.9668*** (0.0138)	0.9867*** (0.0038)	0.9575*** (0.0142)
β_{JPY}	0.0170** (0.0083)	0.0078 (0.0105)	0.0047* (0.0027)	-0.0022 (0.0100)
β_{EUR}	-0.0051 (0.0232)	0.0332 (0.0210)	0.0008 (0.0063)	0.0310*** (0.0125)
β_{GBP}	0.0157 (0.0121)	0.0071 (0.0104)	0.0062* (0.0034)	0.0080 (0.0138)
β_{CAD}	-0.0114 (0.0084)	-0.0034 (0.0095)	0.0029 (0.0032)	0.0130 (0.0114)
σ	0.0697	0.1313	0.0351	0.1242
R^2	0.9844	0.9775	0.9978	0.979

Notes: The dependent variable CNY/CHF is the change in the log difference of the historical USD/CNY price. The standard errors are shown below the estimates. The significance levels are displayed as *** for 1%, ** for 5%, and *for 10%. *Source:* Pacific Exchange Rate Service at UBC.

In Table 6.5, the first period has two potential anchor currencies. The U.S. dollar, with a weight of 0.9822, is significantly different from zero. The Japanese Yen, with a weight of 0.0170, is significant at 5% level. In the second period, the weight of the U.S. dollar remains significant at 0.9668, while in the third period this has increased

to 0.9867. The Japanese Yen and the British Pound have weights at the 10% significance level. It is to be noted that the results of β_{USD} indicate that the RMB exchange rate is mainly pegged to the U.S. dollar. In particular, from 18th February 2009 to 11th June 2010, the R^2 reaches 0.9978. These results are similar to those for the CPR price, as the market USD/CNY exchange rate price also seems tightly pegged to the U.S. dollar. However, this phenomenon is largely a feature of the financial crisis period. In the post-crisis period, the actual market USD/CNY exchange rates are shown to be linked not only to the U.S. dollar, but also to the euro at the 1% significance level.

In summary, comparing the results of the above two methods and two types of data, the findings can be concluded as follows. First, both methods identify 21st June 2010 (Monday) as the regime shift date of the Chinese exchange rate arrangement, regardless of the number of structural breakpoints identified. The market reaction is three working days earlier than the new regime announcement date.⁴⁶ Before this date, or during the financial crisis period, the RMB exchange rate has low variance. After this date, i.e. in the post-crisis period, movements of the RMB exchange rate become more flexible. Second, the U.S. dollar is the dominant currency to which the RMB exchange rate is linked throughout the whole sample period under examination, albeit that on 22nd July 2005 the Chinese government announced the adoption of a managed floating exchange rate regime. Third, after 21st June 2010, when the Chinese government reiterated its intention to reform the RMB exchange rate system,

⁴⁶ On 19th June 2010 (Saturday) the PBOC announced that it would further promote the RMB exchange rate reform to enhance exchange rate flexibility. The model with the market data detects the final period as from 17th June 2010 (Thursday) to 9th October 2012. See Table 6.5 for details of the last period.

movements of the market RMB exchange rate indeed become more flexible, and the rate is no longer pegged only to the U.S. dollar.

6.3.2 Impacts of Exchange Rate Regime Shift across the Global Financial Crisis

In this section this research attempt to discover the impacts of exchange rate regime shifts on RMB exchange rate formation, FX market spreads and the general economy. Due to data availability, our data sample spans from 9th December 2009 to 9th October 2012. As shown before, 21st June 2010 is confirmed to be the date of a critical regime shift in China's exchange rate system. Before this date the RMB exchange rate is almost fixed. Afterwards, movements of the RMB exchange rate become more flexible. In this light, this section focuses on two regimes, the first operating from 9th December 2009 to 18th June 2010, and the second from 21st June 2010 to 9th October 2012. The former is identified as the financial crisis period, and the latter as the post-crisis period.

6.3.2.1 FX Price Formation

The foreign exchange pricing model tested here is the one proposed by Evans and Lyons (2002b). It has been established in the literature that this microstructural model is empirically successful in indicating movements of many currency pairs, while order flow has been found to have a significant power to explain exchange rate returns. In addition, to characterise the impacts of exchange rate regime shift across the global financial crisis, this research develop Killeen et al.'s (2006) approach to introduce a dummy variable $I(RS_t)$ into the empirical formulation. The purpose of including this dummy is to analyse the regime impacts of the post-crisis period. The GARCH (1, 1) method is adopted to capture conditional heteroskedasticity, and both order flow and

interest rate differential are examined in the variance equation. The model specification is shown as follows:

$$\begin{aligned} \Delta P_t &= \mu + \mu_1 I(RS_t) + \gamma OF_t + \gamma_1 OF_t I(RS_t) + \eta IR_t + \eta_1 IR_t I(RS_t) + \varepsilon_t \\ h_t &= \varpi + \varpi_1 I(RS_t) + \phi OF_t + \phi_1 OF_t I(RS_t) + \varphi IR_t \\ &\quad + \varphi_1 IR_t I(RS_t) + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1} + \nu_t \end{aligned} \quad (6.6)$$

where ΔP_t is 100 times the difference of log exchange rate at time t , $I(RS_t)$ is defined as unity if t is later than 21st June 2010 and 0 otherwise. Moreover, OF_t is order flow at time t , IR_t is the interest differential, which is the difference of Chinese interest rate minus the U.S. interest rate, at time t , ε_{t-1} is residual at time $t - 1$ and h_{t-1} is conditional variance at time $t - 1$. Equation (6.6) distinguishes both the intercepts and slope of the post-crisis period from those of the whole sample. This research introduces a benchmark model which contains constant only. Table 6.6 reports the results.

Table 6.6 FX price formation under exchange rate regimes, 2009/12/10-
2012/10/09

Mean Equation								
	μ	μ_1	γ	γ_1	η	η_1	df	
Benchmark	0.00008 (0.00073)	-0.0077** (0.0038)					3.5741*** (0.1079)	
Equation (6.6)	0.0025 (0.0016)	-0.0054 (0.0047)	0.0005** (0.0002)	-0.00006 (0.0003)	-0.0220 (0.0222)	0.0128 (0.0270)	4.0621*** (0.1254)	
Variance Equation								
	ω	ω_1	ϕ	ϕ_1	φ	φ_1	α	β
Benchmark	0.00006*** (0.0000003)	0.0053*** (0.0017)					0.5942*** (0.1194)	0.3207*** (0.1090)
Equation (6.6)	0.00007*** (0.000003)	0.0061*** (0.0016)	0.0000 (0.000003)	-0.0001*** (0.000005)	0.00004 (0.0002)	-0.0011 (0.0013)	0.4271*** (0.1098)	0.1908* (0.1092)

Notes: The estimated coefficients in equation (6.6) are shown in the first row of each model. Standard errors are in the parentheses below. df is the student distribution statistic. The significance levels are displayed as *** for 1%, ** for 5%, and * for 10%.

Table 6.6 shows the estimation results of the benchmark model and of equation (6.6). Both models follow a GARCH (1, 1) process with $\alpha + \beta < 1$. The student distribution statistic is significant, which indicates that exchange rate returns do not follow normal distribution. The benchmark model tells us that the RMB exchange rate in the post-crisis period undergoes a significant appreciation. However, the mean of the whole sample is not significant, which may be due to the regime dependency of the parameters of exchange rates, particularly the changing parameter values in the financial crisis. In addition, the volatility in the post-crisis period is much larger than that of the whole sample. This is consistent with our finding that the RMB exchange

rate is quite stable with low volatility during the financial crisis and becomes more fluctuating in the post-crisis period.

As can be seen in the estimation result of equation (6.6), order flow is positively significant at the 5% level. However, there is no difference in the explanatory power of order flow on exchange rate return between the post-crisis period and the whole sample. Attention is to be paid to the coefficient μ_1 , as it becomes insignificant when this research introduce order flow into the mean equation. This indicates that the appreciation of RMB exchange rate in the post-crisis period is order flow driven. In addition, order flow in the post-crisis period is negatively significant in the variance equation. After 2010, the Chinese government is reported to have set an appreciation target rate of RMB based on the situation of the general economy and on certain policy considerations, for example to guard against an increase of CPI, to relieve the political pressure from the USA, or to prepare for the internationalisation of RMB. Order flow explains the asymmetry effect on exchange rate volatility against the background that the market expects the RMB exchange rate to appreciate. An increase of net buying of the U.S. dollar will slow the appreciation of RMB and reduce its volatility. An increase of net selling of the U.S. dollar will speed the process of appreciation of RMB and make it more fluctuant.

6.3.2.2 The Dynamic Conditional Correlation GARCH Model

This section further analyses the impacts of regime shifts in the Chinese exchange rate system using the DCC methodology, the Dynamic Conditional Correlation model (Engle 2002). This chapter apply the method first to explore the dynamic relation between the market spread and the possibility of government intervention. Then, this

research deploys the model to gauge the economic significance of exchange rate exposure in China. The tests are conducted across the global financial crisis with two regimes, and then individually in the financial crisis and post-crisis periods.

Numerous studies use the ARCH-type models to investigate the volatility of the foreign exchange market. Engle (1982) introduced the seminal ARCH-type model for estimation and forecasting of the volatility of time series data. Many extensions of this model have emerged and are widely used in financial studies. The models can be classified into two main types: the univariate and multivariate GARCH models. According to a survey by Laurent (2009), the univariate GARCH models include the GARCH, EGARCH, GJR, FIEGARCH and HYGARCH. The multivariate GARCH models include the BEKK, CCC, DCC, DECO and GOGARCH. Following Engle (2002) the DCC model can be defined as:

$$y_t = \mu_t(\theta) + H_t^{1/2}(\theta)z_t \quad (6.7)$$

$$H_t = D_t R_t D_t$$

$$R_t = \text{diag}(q_{11,t}^{-1/2} \dots q_{NN,t}^{-1/2}) Q_t \text{diag}(q_{11,t}^{-1/2} \dots q_{NN,t}^{-1/2}) \quad (6.8)$$

$$D_t = \text{diag}(h_{11,t}^{-1/2} \dots h_{NN,t}^{-1/2})$$

where the past observations' vector $\{y_t\}$ is a $N \times 1$ matrix, the $\mu_t(\theta)$ is the conditional mean vector of y_t and the $H_t^{1/2}(\theta)$ is a $N \times N$ positive definite matrix; the $N \times 1$ random vector z_t is the standardised residuals, H_t is the conditional variance of y_t , R_t

is a $N \times N$ symmetric dynamic correlations matrix and finally D_t is a diagonal matrix of conditional standard deviations. Then, the Glosten et al. (1993) GJR (p, q) can be displayed as:

$$h_{iit} = \omega_i + \sum_{q=1}^{q_i} (a_{ip} \varepsilon_{i,t-p}^2 + c_{ip} S_{t-i}^- \varepsilon_{i,t-p}^2) + \sum_{p=1}^{p_i} b_{ip} h_{iit-p} \quad (6.9)$$

$$i = 1, \dots, N.$$

where S_t^- is a dummy variable; when c_{ip} is negative (positive) it is valued as 1 (0). In the DCC model, the $N \times N$ symmetric matrix $Q_t(q_{ij,t})$ is given as:

$$Q_t = (1 - \alpha - \beta) \bar{Q} + \alpha u_{t-1} u'_{t-1} + \beta Q_{t-1} \quad (6.10)$$

where, $u_t = \varepsilon_t / \sqrt{h_{iit}}$, \bar{Q} is the $N \times N$ unconditional variance matrix of u_t ; α and β are non-negative scalar parameters, and $\alpha + \beta < 1$ is the condition for stationary unconditional correlation. Therefore, for the two markets the conditional correlation at time t for the DCC of Engle (2002) can be defined as

$$\rho_{12t} = \frac{(1 - \alpha - \beta) \bar{q}_{12} + \alpha u_{1,t-1} u_{2,t-1} + \beta q_{12,t-1}}{\sqrt{((1 - \alpha - \beta) \bar{q}_{11} + \alpha u_{1,t-1}^2 + \beta q_{11,t-1})((1 - \alpha - \beta) \bar{q}_{22} + \alpha u_{2,t-1}^2 + \beta q_{22,t-1})}} \quad (6.11)$$

Where q_{12} is the element on the 1st row and 2nd column of the matrix Q_t . According to Laurent's (2009) survey of Engle's (2002) DCC model, the estimation includes two steps. The first step is to estimate the univariate GJR (1, 1) model to get the standard residuals. The second step is to use the intercept parameters of conditional correlation to estimate the coefficients of the dynamic correlation.

6.3.2.3 Market Spreads and Intervention Possibility

There are many studies investigating the intervention effect in the foreign exchange market with intraday frequency. In a recent study, Melvin et al. (2009) collect 5 days' data to investigate the effect of exchange rate intervention by the Russian Central Bank on market spread in 30 second intervals. Their results show that intervention does widen the intraday market spread. Fatum et al. (2013) study the intervention by the Danish central bank, intended to manage the currency with a crawling band around a major currency. They find that the intervention effect on exchange rate spread is asymmetric when the market expects the currency to appreciate. In this case, intervention purchase of the currency decreases exchange rate spread, while intervention sale increases the spread.

Owing to the lack of availability of intraday data of Chinese monetary authority intervention, it is impossible for us to focus directly on intervention effects on market spread. Instead, this research introduce a variable, deviation of transaction price from the CPR, to indicate the possibility of intervention and study its dynamic correlation with market spread in two exchange rate regimes: from 9th December 2009 to 18th June 2010 as the financial crisis period, and from 21st June 2010 to 9th October 2012 as the post-crisis period. Following the findings of Fatum et al. (2013), this section

divide this new variable into positive deviation and negative deviation to study the asymmetric relation between the deviation and the bid-ask exchange rate spread. While the construction of PDC and NDC is asymmetric, this research adopts a DCC AR (1)-GJR (1, 1) model to study the relation with spread in half day intervals. Our model also considers order flow.

Table 6.7 shows the results of the DCC AR (1)-GJR (1, 1) model for bid-ask spread, PDC, NDC and order flow. From Panel A, we see that the asymmetric effect on variance of all the variables is not significant during the financial crisis period. It is however significant for PDC and NDC in the post-crisis period. The GJR model captures the asymmetric construction of PDC (NDC), which is the distance of deviation from the CPR when the transaction price is larger (smaller), and is 0 otherwise. The multivariate residual follows a student distribution, while df and normality test in Panel B are significant in both the financial crisis and post-crisis periods.

Table 6.7 DCC-GJR of market spread, order flow and possibility of intervention,

2009/12/09-2012/10/09

Panel A. The Univariate GJR (1,1) Model with Student-t distribution								
	Financial Crisis Period				Post-Crisis Period			
	Spread	PDC	NDC	OF	Spread	PDC	NDC	OF
ω_i	988.26 (11065)	635.8 (2650.9)	18153.77 (44767)	9.7222* (5.5689)	0.00007 (0.0004)	0.0050* (0.0027)	0.0011 (0.0007)	9.3233 (8.5385)
a_i	0.0246 (0.0441)	1.5906*** (0.6019)	0.1915 (1.1997)	0.6009** (0.2772)	0.1157 (0.1453)	0.3715** (0.1447)	-0.0296 (0.0250)	0.0012 (0.0236)
b_i	0.8414*** (0.1848)	0.2928*** (0.0679)	0.7689*** (0.1526)	0.5441*** (0.1435)	0.7806*** (0.0929)	0.7740*** (0.0809)	0.8216*** (0.0464)	0.9307*** (0.0433)
c_i	46.1582 (128.88)	2.9556 (2.0297)	-0.1443 (1.0675)	-0.3989 (0.3519)	1.7426 (1.1501)	-0.3341*** (0.1164)	0.4080*** (0.1344)	0.0420 (0.0417)

Panel B. The DCC-GJR (1, 1) Model								
	ρ_{SP}	ρ_{SN}	ρ_{SO}	ρ_{PN}	ρ_{PO}	ρ_{NO}	α	β
Financial								
Crisis	0.4079*** (0.0663)	0.2317*** (0.0659)	0.0361 (0.0569)	0.3269*** (0.0468)	0.1276** (0.0585)	0.2677*** (0.0522)	0.0204 (0.0238)	0.2123 (0.2337)
Post-Crisis	0.4522*** (0.1292)	0.1004 (0.1623)	-0.0770 (0.0648)	0.0798 (0.1107)	0.0339 (0.0732)	0.0616 (0.0667)	0.0109*** (0.0023)	0.9856*** (0.0032)

The DCC-GJR (1, 1) Model (Continued)			
	df	Log-likelihood	Vector normality [Prob.]
Financial			
Crisis	3.0102*** (0.1273)	956.968	1236.6*** [0.0000]
Post-Crisis	3.3605*** (0.1002)	-2426.701	6642.1*** [0.0000]

Notes: The variable 'Spread' is the ask price minus the bid price at the end of the half day, corresponding to the last transaction price multiplied by 100. 'PDC' is the positive deviation of transaction price from the CPR at the end of the half day multiplied by 100. 'NDC' is the negative deviation of transaction price from the CPR at the end of the half day multiplied by 100. 'OF' is net of the buyer initiated and seller initiated trades. The standard errors are shown below the estimates. The significance levels are displayed as *** for 1%, ** for 5%, and * for 10%. The subscripts 'S', 'P', 'N' and 'O' denote market spread, PDC, NDC and order flow, respectively. df is the student distribution statistic.

During the financial crisis, both PDC and NDC are positively correlated with bid-ask spread. It can be seen from Figure 6.6 that the CPR is almost unchanged during the financial crisis. As a management tool, the Chinese government maintains an almost fixed CPR, which delivers a strong political signal to the market that the government intends to keep the exchange rate stable. Any deviation of the transaction price from the CPR will probably lead to intervention from the Chinese government. The possibility of intervention thus increases and the exchange rate spread widens.

A larger coefficient of correlation between PDC and the spread than that between NDC and the spread indicates that the market expects the Chinese government to prefer appreciation of the RMB exchange rate rather than depreciation. A plausible reason for this is that depreciation of the RMB will decrease the returns and increase the risk to foreign investment. This could make foreign investment and international capital flow out of China and further worsen the economy during the financial crisis. Consistent with the price formation of the exchange rate, order flow has positive correlation with both PDC and NDC. Net of buyer initiated and seller initiated trades will push the transaction price to deviate from the CPR. The correlation mentioned is constant, while α and β are not significant.

In the post-crisis period, only PDC is significantly correlated with the bid-ask spread, and the correlation is time-varying. As can be seen in Figure 6.6, the CPR becomes more flexible in the post-crisis period and gradually appreciates. Either the Chinese government makes the CPR appreciate and then pushes the RMB exchange rate to appreciate in order to achieve the annual appreciation target, or the market expects the RMB exchange rate to appreciate and then forces the CPR to appreciate. In either case, the RMB exchange rate is rarely far below the CPR in the post-crisis period of our

sample. However, after August 2011, we see frequent disagreement between the market and government. The CPR gradually appreciates and becomes stable, but the market exchange rate is frequently higher above the CPR. Government control and politics are perhaps the main reasons for the deviation, while ρ_{PO} and ρ_{PN} are no longer significant. The frequently large PDC, contrary to the government's intention, increases the possibility of intervention and widens the bid-ask spread.

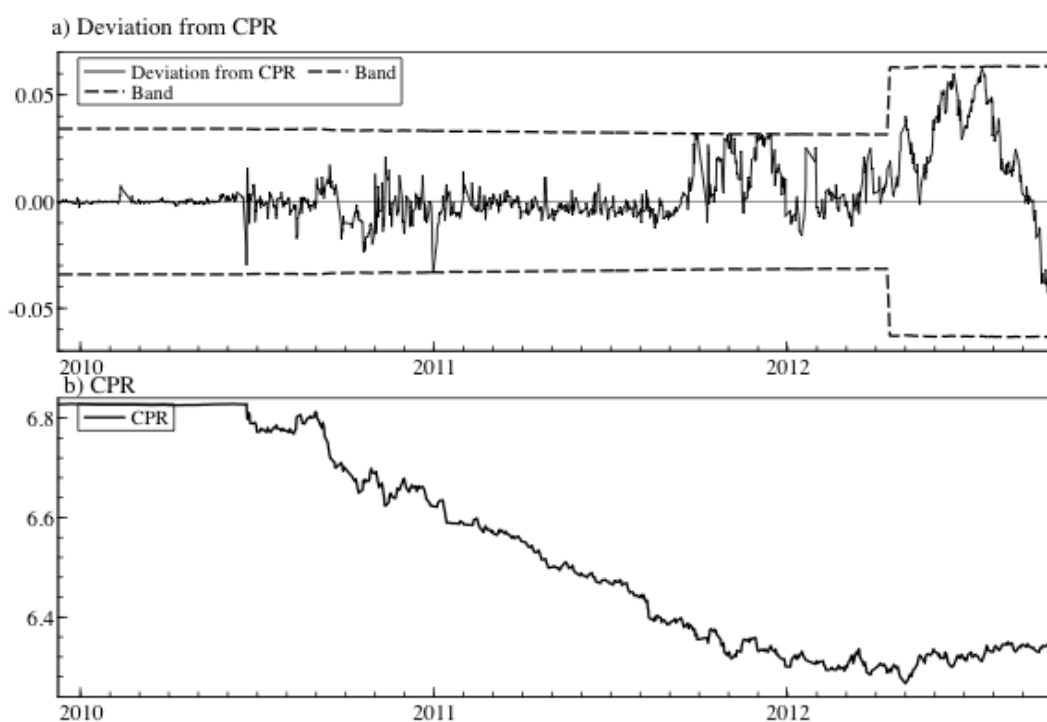


Figure 6.6 Time series of CPR, deviation from CPR and CPR crawling band

2009/12/09-2012/10/09

6.3.2.4 The Economic Significance of the RMB Exchange Rate Exposure

Before investigating the economic significance of the exchange rate exposure during the financial crisis and post-crisis periods, this section first review the theoretical linkage between the exchange rate and the stock index price. Two main approaches have been used to investigate this linkage. First, the ‘flow oriented’ model assumes that there is a positive relation between the exchange rate and the stock index price (Dornbusch and Fischer 1980).⁴⁷ If the value of domestic currency is decreased, exports become cheaper and so will increase. Firms in international trade will gain more income from the increased exports, thus their stock price will be increased. Second, the ‘portfolio balance model’ indicates that there is a negative relation between the exchange rate and stock prices (Frankel 1987).⁴⁸ If local stock price appreciates, this will prompt investors to adjust their portfolio. They will sell foreign assets in order to have enough domestic currency to buy more domestic assets; thus the domestic currency will depreciate.

To acquire further insights regarding the Chinese exchange regime shifts across the global financial crisis, this research explore whether currency exposure is economically significant and relevant to investors during the financial crisis and post-crisis periods. Following Muller and Verschoor (2007), this research adopt the AR (1)-GJR (1, 1) model to specify conditional heteroskedasticity in the basic regression model. The RMB currency exposure can be computed by the following equation:

⁴⁷ For details, see Dornbusch and Fischer (1980); see also Aloui (2007).

⁴⁸ The complete portfolio balance model is given by Frankel (1987).

$$R_{c,t} = \alpha + \beta R_{e,t} + \gamma P_t + \varepsilon_t \quad (6.12)$$

$$\text{with } \varepsilon_t = u_t * \sqrt{h_t} \text{ and } h_t = \omega + a\varepsilon_{t-1}^2 + bh_{t-1} + cS_t^- \varepsilon_{t-1}^2$$

where, $R_{c,t}$ denotes the returns to the equity index, here the MSCI China index;⁴⁹ α is the constant; $R_{e,t}$ is the returns to the overall stock market index, here the MSCI Emerging Market index; β stands for the sensitivity of market fluctuations; P_t is the returns of the RMB exchange rate against the U.S. dollar;⁵⁰ γ then indicates the RMB currency exposure to fluctuations of the USD/CNY exchange rate; h_t is the conditional variance of the residuals; ε_{t-1}^2 is the squared residual from the mean equation; S_t^- is a dummy variable: when c is negative (positive) it is valued as 1 (0); u_t is the error term.

⁴⁹ MSCI China index as a benchmark of the overall performance of the Chinese stock market.

⁵⁰ In previous work, this research find USD/CNY is the dominant currency pair in the China FX market.

Table 6.8 Estimation results of RMB currency exposure 2009/12/09-
2012/10/09

Panel A: The AR (1)-GJR (1, 1) model								
	Mean Equation				Variance Equation			
Parameters	α	β	γ	ω	a	b	c	df
Financial	0.0002***	0.9733***	-4.059***	0.5359***	-0.159***	0.3774***	0.1321***	391.26***
Crisis								
Period	(0.000002)	(0.0000005)	(0.000009)	(0.0000005)	(0.0000005)	(0.0000006)	(0.0000003)	(1.1344)
Post-crisis	-0.0001	1.0114***	0.1752	0.0112*	0.0901***	0.9400***	-0.0967*	18.1607
Period	(0.0003)	(0.0476)	(0.3706)	(0.0067)	(0.0243)	(0.0271)	(0.0524)	(11.493)

Panel B: The DCC AR (1)-GJR (1, 1) model								
Parameters	ρ_{CE}	ρ_{CP}	ρ_{EP}	α	β	df	Log-likelihood	Vector normality [Prob.]
Financial	0.7944***	-0.2259***	-0.1812**	0.0490	0.0000	11.8566*		32.335***
Crisis							1739.831	
Period	(0.0261)	(0.0874)	(0.0867)	(0.0633)	(0.2157)	(6.3594)		[0.0000]
Post-crisis	0.7952***	-0.2975***	-0.3005***	0.0307	0.4016***	10.5863***		91.909***
Period	(0.0139)	(0.0389)	(0.0371)	(0.0219)	(0.1413)	(2.1071)	6712.127	[0.0000]

Notes: The RMB currency exposure γ is reported in the Table. The variable P_t is change of the log USD/CNY exchange rate. Log difference of the Emerging Market Index and the MSCI China index are denoted as variables $R_{e,t}$ and $R_{c,t}$, respectively. Panel A of the table shows the estimation results of equation (6.12) based on the AR (1)-GJR (1, 1) model while Panel B shows the DCC-GJR model estimation of P_t , $R_{e,t}$ and $R_{c,t}$. Subscripts 'C', 'E' and 'P' denote the MSCI China index $R_{c,t}$, Emerging Market index $R_{e,t}$ and RMB exchange rate P_t , respectively. df is the student distribution statistic. The standard errors are shown below the estimates. The significance levels are displayed as *** for 1%, ** for 5%, and *for 10%.

Table 6.8 shows the estimation results of economic significance of the RMB currency exposure. The table includes two panels. Panel A reports the estimation results of equation (6.12) based on the univariate AR (1)-GJR (1, 1) model, which is assumed to follow the student t distribution. It can be seen that the coefficient on the exchange rate γ indicates that the RMB currency exposure is negatively significant at the 1% level in the financial crisis period. The negative coefficient on the exchange rate γ suggests that the USD/CNY exchange rate has a negative impact on the returns of the Chinese stock market. However, the results show insignificant effects of currency exposure on the Chinese stock market during the post-crisis period. In this period, the Chinese stock market is less exposed to exchange rate movements, possibly because by manoeuvring the currency weights of the reference basket the Chinese monetary authority has minimised the effect of dollar movements. In the variance equation the squared residual term a and the coefficient on the variance term b are all statistically significant at the 1% level.

Panel B of the table 6.8 shows the correlation between the RMB exchange rate, the MSCI China index and the Emerging Market index specified in the DCC AR (1)-GJR (1, 1) model. In all periods, the returns of both the MSCI China index and the Emerging Market index are negatively correlated with the RMB exchange rate at the 1% significance level. These results are consistent with the portfolio balance model. Meanwhile, the coefficients of correlation between each market index are positively significant at 1% level. There are no significant differences in the correlation between each market index and the exchange rate during the two periods. The results of this Chapter can be summarized in the following table:

Table 6.9 The major findings of regime shifts

A. Identify the exact timing of regime shifts (22/07/2005 – 09/10/ 2012)	
a) The Markov Switching Model (Engle and Hamilton, 1990)	<i>The CPR:</i> Regime 0 (high frequency), 22/6/2010 to 09/10/2012; Regime 1 (low frequency), 22/12/2008 to 21/06/2010 (Mon)
	<i>The market exchange rate:</i> Regime 1, 24/03/2009 to 17/06/2010
b) Currency Basket Composition (Zeileis et al., 2010)	<i>The CPR:</i> 4 breakpoints; Last period, 22/06/2010 to 09/10/2012
	<i>The market exchange rate:</i> 3 breakpoints; Last period, 17/06/2010 to 09/10/2012
B. The different impacts of regime shifts (09/12/2009 – 09/10/2012)	
a) FX price formation	<i>The financial crisis period:</i> low volatility <i>The post-crisis period:</i> RMB appreciation is order flow driven Larger volatility
	<i>The financial crisis period:</i> PDC and NDC positively correlated with bid-ask spread Preference for RMB appreciation. <i>The post-crisis period:</i> only PDC is positively correlated with bid-ask spread CPR becomes more flexible.
b) Market spreads and intervention possibility	<i>The financial crisis period:</i> Exchange rate has negative impact on stock markets <i>The post-crisis period:</i> Insignificant effects of currency exposure
c) Economic significance of RMB exchange rate exposure	

6.4 Conclusions

This chapter examines the regime shift in the Chinese exchange rate system from a microstructural perspective. Our findings shed critical light on the behaviour of the Chinese exchange rate policy and its responses to the global financial crisis. Two complementary methods are deployed to detect and date the regime shifts in the Chinese exchange rate system, one based on the policy driven exchange rate (CPR), and one on the market exchange rate.

Under both approaches, two policy regimes are detected during the sample period. The date of the regime switching is identified as around 21st June 2010, which is also the first business day after Saturday 19th June, the date when the Chinese central bank restated its intentions for reform of the exchange rate system. Compared to the first reform statement, this time the Chinese central bank declared more forcefully the intention for a bolder and deeper exchange reform. More importantly, since that date the actual policy course has changed.

Evidence unearthed by this study shows that there is a ‘fear of floating’ in China. Despite the public declaration of the adoption of a ‘managed floating exchange rate system’, at this stage the system shows only a timid process of RMB appreciation. Exchange rate flexibility, an essential quality of a managed floating rate system, is essentially absent. It is only recently that flexibility has been instilled into the system and our evidence shows that prior to 21st June 2010, the RMB exchange rate remained almost fixed. Since that date, it has shown more flexibility. System flexibility is also reflected in the changing composition of the Chinese basket of currencies. While

generally the U.S. dollar is the dominant currency in the basket, the evidence shows that after 21st June 2010 the RMB is no longer pegged only to the U.S. dollar.

Our test for the impacts of China's shift of exchange rate regime starts with the estimation of the foreign exchange pricing model from a microstructural perspective. This chapter find that order flow has significant power to explain changes in exchange rate returns under different regimes. However, the appreciation process of the RMB exchange rate in the post-crisis period is found to be largely order flow driven. In addition, order flow has an asymmetric impact on exchange rate volatility, while RMB exchange rate is expected to appreciate.

A DCC AR (1)–GJR (1, 1) model is applied to investigate the dynamic relation between the bid-ask spread and the intervention possibility proxied by deviations of the transaction price from the CPR. In the financial crisis period, the Chinese government's intention to keep the exchange rate stable means that deviations from the CPR tend to increase the possibility of intervention, and thus the possibility of intervention correlates with the bid-ask spread. Furthermore, PDC (positive deviation from CPR) is found to be less favoured by the government than NDC (negative deviation from CPR). In the post-crisis period, deviation of transaction price from the CPR is still asymmetrically correlated with the bid-ask spread. When the Chinese government prefers a gradual appreciation process PDC is significant but NDC is not, and the correlation becomes time-varying.

Using the AR (1)-GJR (1, 1) model, this chapter examine the economic significance of currency exposure in China across the regimes and in different periods of the global financial crisis. Evidence indicates that, at the national level, currency exposure

is highly significant and negative in China during the crisis period. However, in the post-crisis period, the exposure becomes insignificant. This may be a result of China's changing the composition of the reference currency basket, which reduces the effects of fluctuations of the dollar on the variability of the Chinese official CPR and the market exchange, and of the pass-through of currency exposure to domestic financial markets.

This chapter tries to detect the de facto exchange rate regime of China and to estimate the impact of the regime shifts. The results indicate that the government has a general appreciation target on the RMB exchange rate. Behind this trend, there are two main factors driving the regime changes. First, the Chinese government is attempting to ease the political pressure from the USA. According to a recent Reuters News report (6th June 2013), the US government has tried to renew Senate pressure against China currency manipulation, declaring that the Chinese RMB remains undervalued. As part of the efforts of relieving such kind of pressure, the Chinese government is inclined to change the nation's exchange rate regime. Second, and most importantly, the Chinese government changes the exchange rate regime with a view to making preparations for the rise of the RMB as an international currency. Deputy governor Mr Yi Gang has stated that the central bank should adopt a global perspective because the RMB will become one of the world's important currencies (PBOC, 2008). That is consistent with the evidence of this research showing that the RMB exchange rate is no longer pegged only to the US dollar.

The findings of this chapter reveal the Chinese government's changing focus on the exchange rate arrangements. Working in tandem with the previous chapter, research in this chapter sheds critical lights on the critical aspects of the Chinese exchange rate

policy, i.e. how intervention operation is conducted by the Chinese monetary authority on the foreign exchange market and the property of the de facto Chinese exchange rate regime. Findings about these aspects help advance our knowledge of the Chinese exchange rate policy.

Chapter 7

Chapter 7 Conclusions

This chapter summarises the main findings and implications of this thesis, and makes suggestions for future work.

Chapter 7

Conclusions

7.1 Main Findings

This thesis aims to better our understanding of China's exchange rate policy in a period of fundamental economic transition and global financial crisis. Taking a market microstructural perspective, this research investigate the long-term determination and short-run dynamics of the RMB exchange rate, the intervention by the Chinese monetary authority in the marketplace, and the regime shifts in the Chinese exchange rate system.

This thesis begins by presenting an overview of the microstructure of the Chinese foreign exchange market, and the evolvement of the country's exchange rate regime. This lays down the institutional foundation for our later discussions. Next, this research estimates the explanatory power of order flow for exchange rate movements in a structural VAR setting. The focus is the relation between order flow and exchange rate in the long run and short run. This research test for the empirical implications of the Portfolio Shift model (Evans and Lyons 2002b) and estimate the cointegrating relations in the system with the trace test (Johansen 1995). A graph-theoretic method is applied to find the instantaneous causal relations (Demiralp and Hoover 2003).

In the variable space containing order flow, macro influences and the exchange rate, this research find evidence of the long-term cointegrating relation among order flow and the other variables under examination. The short-run dynamics show that, in the new regime of Chinese exchange price formation, order flow as a measure of 'signed' trading volume is able to explain a significant part of the short-term fluctuations in the RMB-dollar exchange rate.

The outcome of impulse responses analysis indicates that order flow responds immediately and more strongly than other variables (excluding exchange rates themselves) to the exchange rate movements over the short horizon. In the long run, the interest rate differential has a stronger influence on exchange rate movement. Country risk premium shows a similar tendency but to a lesser extent (Zhang, Chau, and Zhang 2012).

The study of foreign exchange intervention is always and everywhere a challenging task. This is especially so in the Chinese case, because the government tends to cover its intervention activity with great secrecy. This thesis explores Chinese intervention in a framework that allows for multiple perspectives based on high-frequency data.

This research first identifies the intervention from an extensive range of news media reports, and establishes the typology of China's intervention. Then, reduced-form estimation is conducted to examine the effects of intervention on the order flow and on the exchange rate. Next, this research tests the sensitivity of exchange rate returns to order flow when intervention occurs. Interactions between the exchange rate return and order flow are tested in a VAR model. A set of five success criteria is deployed to examine the effectiveness of the Chinese intervention. Finally, a GARCH analysis is

conducted to check the robustness of our empirical findings. In the process, the tests shed additional insight on the impacts of intervention on volatility.

In general, the Chinese intervention takes the form either of setting the central parity rate and the allowed band for RMB exchange rate fluctuation (CPR intervention); or of the central bank issuing instructions or guidance regarding market transactions via the state-owned banks, or engaging directly in sales or purchase of foreign currencies (CB intervention). This research find that intervention not only impacts directly on changes in the exchange rate, but also affects the buying – selling pressure, or order flow. Intervention is more likely to occur when there are heavy selling orders with little liquidity, and where the exchange rate deviates from the central bank’s tolerable level. In other words, it is more likely that the Chinese authority would move to arrest currency devaluation.

Order flow is found to be positively and significantly correlated with the exchange rate when intervention occurs. Order flow carries additional information under CB intervention, while CPR intervention tends to cause a change of the impact sign when the government resorts to devaluation-targeting intervention. Decomposition analysis shows that the portion of intervention effect that is directly impounded into the exchange rate plays a more prominent role than that via the order flow. CB intervention can effectively influence both the exchange rate and the order flow, while CPR intervention is effective in keeping the exchange rate within the fluctuation band.

The robust test confirms the main findings of the thesis, and reveals additional evidence that while CB intervention can influence the exchange rate and order flow, it tends to increase the volatility. Meanwhile, CPR intervention can play some role in a

‘leaning against the wind’ policy, in that it may slow the net order flow out of the dollar, but it cannot reverse the trend.

This thesis next examines the Chinese government’s changing of its exchange rate regime in a time of global financial crisis. To detect the switch to a de facto regime and its timing, this research apply two complementary regime switching models, by Engel and Hamilton (1990) and by Zeileis et al. (2010). Having identified the dates of regime shift and the currency weights in the reference basket, this research deploy a multiple GARCH model to find the impacts of the exchange rate regime shift across the global financial crisis.

This research find that the exchange rate of RMB had low variance, so that it was almost fixed, before 21st June 2010, but that the exchange rate volatility became more flexible after that date. The US dollar maintained the greatest weight in China’s reference basket throughout the entire period. However, there is significant evidence that since 21st June 2010, the RMB has no longer pegged only to the US dollar.

The RMB exchange rate appreciation process is largely order flow driven in the post-crisis period, but the pricing model shows no evidence of any different characteristics in the post-crisis period. Meanwhile, order flow has asymmetric impacts on the RMB exchange rate volatility when the exchange rate is expected to appreciate.

This research finds that Positive Deviation from the central parity price (PDC) has been less favoured by the government than Negative Deviation from the central parity (NDC). The PDC is significant, indicating that the Chinese monetary authority prefers to promote a gradual appreciation of the RMB exchange rate. However, the NDC is not significant and the correlation becomes time-varying. It is interesting to note that

deviations of transaction price from the central parity would increase the possibility of Chinese intervention; thus intervention correlates with bid-ask spreads. The empirical results show that, in the financial crisis period, the currency exposure is predominantly negative.

7.2 The Implications of This Research

The implications of this research can be summarized as follows: First, employing a microstructure approach based on high-frequency data, the research sheds critical lights on the RMB determination in the market transaction process. It shows that consideration of the trading system in the study of the Chinese exchange rate behaviour can provide a deeper understanding of the foreign exchange policy of China, while focus on buying and selling pressure allows a closer examination of the exchange rate movements. The results indicate that order flow has significant explanatory power to capture the RMB exchange rate variability. The results bring to the attention of the Chinese monetary authority the importance that should be attached to the market microstructure.

Second, in unveiling the mystery of Chinese intervention with a multi-dimensional approach based on high-frequency data, this research establishes how the Chinese monetary authority works to intervene in the market place, and the consequences of government activity in this area. The results show the efficiency of the Chinese government intervention. Policy makers should note that central bank interventions can increase volatility and that while CPR intervention plays a role in ‘leaning against the wind’, it cannot reverse the basic trend.

Further, this research provides evidence of the de facto exchange rate regime of China and the findings about the impacts of the exchange rate regime shift in China across the global financial crisis. The outcome unveils the true property of Chinese exchange rate system and its consequences, which offers an important input to a better understanding of the Chinese exchange rate policy by the global policy circle, academic community and international business world.

7.3 Future Research

Several interesting areas have emerged for further research. In addition, the limitations of this research can be listed below.

Firstly, data availability permitting, increasing the number of currency pairs seems a promising direction, to test for the China foreign exchange market in cross section and to see a fuller picture of how the Chinese foreign exchange market works and interacts with the government. Another promising area for study would be research into the empirical techniques of detecting the macroeconomic news impact on the RMB exchange rates against the dollar and other currencies. This may also shed new critical light on how differently the RMB-dollar and RMB-other currency rates respond to the same type of shock.

Secondly, the limitations the research on intervention in China has two aspects. First, future work should consider more market forces variables. It will be interesting to see how robust the estimation of the intervention is when controlling for market variables. The second limitation of this research is the lack of government intervention information. Future work should further dig out relevant information in this area, particularly discussions by economists and think tanks. Making comparison between

the officially stated intention and the research evidence will offer critical insight on the Chinese foreign exchange policy.

Thirdly, this research applies the microstructure approach to analyse the Chinese foreign exchange market. However, this thesis is limited with regard to drawing insights for the research in the macro models, especially the research on intervention from the macroeconomic perspective. Future research should seek to deploy relevant variables that can reflect information of the macroeconomic fundamentals but can also have micro data availability.

Furthermore, future research may divide a longer sample into several sub-periods based on the regime shifts in the Chinese exchange rate system. This will facilitate discovery of the fuller impacts of regime shifts, with particular reference to the periods before and after the global financial crisis, and will also allow investigation of the time-varying effects of order flow on the formation of the exchange rate.

In assessing the consequences of regime shifts in the exchange rate system, one may take into consideration new developments in asset pricing models, such as new CAPM models or APT models, and also incorporate other factors such as the degree of exchange rate pass-through or evolving pricing practices in different countries and at different stages within a country.

Appendix

Data Sources

Data sources	Data type & Official website
CFETS (China Foreign Exchange Trading System)	Foreign exchange rates http://www.chinamoney.com.cn/en/index.html
Thomson Reuters DataStream Professional	Integrated economic research data https://forms.thomsonreuters.com/datastream/
Factiva	Online news databases http://www.dowjones.com/factiva/index.asp
Federal Reserve System: Foreign Exchange Rates	Foreign exchange rates http://www.federalreserve.gov/releases/h10/Hist/
Olsen Data	Databases of tick-by-tick prices http://www.olsendata.com/data_products/welcome/
Pacific Exchange Rate Service	Foreign exchange rates http://fx.sauder.ubc.ca
PBOC (The People's Bank of China)	Government public information http://www.pbc.gov.cn/publish/english/963/index.html
Reuters China	Reuters China headlines http://cn.reuters.com
Reuters 3000 Xtra	Information and transaction service http://www.trpropresearch.com/products/Reuters3000Xtra/
SAFE (State Administration of Foreign Exchange)	China's foreign exchange public information http://www.safe.gov.cn
Wind Info.	Financial information of the Chinese market http://www.wind.com.cn/En/Default.aspx

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