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Foreign Exchange Intervention in China

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

Department of Economics and Finance
Durham University Business School
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September 2016

To My Grandparents and Parents

Foreign Exchange Intervention in China

He Li

PhD (Finance)

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September 2016

Abstract

This thesis investigates the behaviour of foreign exchange intervention in China and its effects on the RMB's exchange rate levels and volatility. The research first examines what drives Chinese central bank's intervention through buying and selling foreign exchange (the CB intervention) in a bivariate probit model and shows that intervention is driven by an array of factors including exchange rate deviations, conditional volatility, national economic conditions, interest rate differentials. The PBOC conducts intervention in a leaning-against-the-wind fashion in the medium term, while leaning-with-the-wind intervention is used in the short term.

The thesis next focuses on the intervention in the central parity rate (the CPR intervention). Evidence from a Bayes Tobit model shows that the CPR intervention is determined by the market price (proxied by the proposed price by designated market makers), broad currency index and the yield curve spread. The PBOC adopts a leaning-against-the-wind strategy for the intervention in that when the market price appreciates (depreciates), the PBOC sets a higher (lower) central parity rate to dampen or even reverse the appreciation (depreciation).

To what extent the CB and CPR interventions are effective is then estimated in threshold GARCH models. Results show that while CPR intervention focuses on combating appreciation, intervention by the central bank's purchase or sale operations (CB intervention) impacts on exchange rate levels when the RMB depreciates. While interventions would move exchange rate levels to the direction desired by the authorities, they tend to increase exchange rate volatility.

Finally, event study methodology is deployed to explore the properties and impacts of China's oral intervention. The estimation adopts four criteria (event, direction, reversal and smoothing) to test to what extent oral intervention is effective. Evidence indicates oral intervention through exchange rate communications can influence exchange rate levels and the RMB exchange rate is responsive to international pressure. Furthermore, sequential oral interventions can reduce exchange rate volatility.

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During my whole life, my dad and mom have believed in me and supported me as I have pursued my dreams. Dad taught me to try my utmost to achieve my goals, and inspired me to reach my potential. Mom shows me wisdom and how to be a better person. My grandmother, grandfather and other relatives always support me and worry about me when I am abroad. I promise I will spend more time with you in future. I love you all. I hope my Dad and Mom have good health, and my Dad can be recovered very soon.

I want to thank my office colleagues for their supports and helps during my PhD studies.

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

Introduction

In recent decades, China's exchange rate policy has been the subject of much debate. One crucial aspect of China's exchange rate policy is the country's official intervention in the foreign exchange market. Given the nation's rising importance in the world economy, and the growing openness of the Chinese foreign exchange market, it is desirable, although challenging, to achieve a better understanding of the forms, determinants, strategies and consequences of China's intervention. By exploring into these fundamental issues, this research attempts to contribute to the on-going debate with a clearer picture of China's exchange rate policy and hence to enrich the literature on a crucial issue that is having global repercussions.

1.1 Motivations and Research Questions

Until the 1990s and early 2000s, advanced countries, such as the US and Japan, frequently used foreign exchange intervention to influence exchange rate movements (Kim and Sheen, 2002; Ito and Yabu, 2007). However, since then, as intervention operations have become much less common in advanced markets, researchers have paid increasing attention to interventions in the emerging markets, such as Turkey (Akinci et al., 2006; Herrera and Ozbay, 2005), Argentina (Brause, 2008) and Pakistan (Mehdi et al., 2012), where this tool is now used extensively. Among the emerging economies, China in particular is regarded as using intervention frequently and to have significant effects. This issue is being watched

internationally, and has become so charged that since 2005 there have been several bipartisan attempts in the US Congress trying to label China as a currency manipulator and to implement punitive actions accordingly.¹ However, despite the great international concern and the potential global impacts, there is a surprising lack of studies of China's foreign exchange intervention. This thesis is intended to fulfil this crucial void in the literature.

In addition to offer a better and fuller picture of how China's monetary authorities determine the intervention decision, the second motivation of this thesis is to research the effects of intervention on China's foreign exchange market and therefore to achieve a better understanding of China's exchange rate policy. In conducting interventions as an important policy instrument to influence the foreign exchange market, central banks have two main objectives, which are to move the level of the exchange rate in the intended direction, and to calm excessive volatility in terms of both the level and the speed of fluctuation (Utsunomiya, 2013). However, empirical studies find that intervention can actually move the exchange rate in the wrong direction (Baillie and Osterberg, 1997; Galati et al., 2005), or increase exchange rate volatility (Dominguez, 1998; Baillie et al., 2000; Nagayasu, 2004; Beine et al., 2009). Such an outcome could happen to China's intervention operations as well. This research intends to determine to what extent China's intervention is effective in meeting the intended objectives.

¹ In 2005, the first Chinese currency bill was put forward by Senators Charles Schumer (Dem., New York) and Lindsey Graham (Rep., South Carolina). Both parties pushed modified bills in September 2010 in the House of Representatives and in October 2011 in the Senate. However, these later failed to become law.

This thesis aims to achieve a better understanding of China's exchange rate policy by offering a comprehensive investigation of China's official intervention in the foreign exchange market. China's foreign exchange intervention is a complex system that takes three major forms, namely CB intervention i.e. intervention by the central bank through buying and selling foreign exchange, CPR intervention, i.e. the central bank's intervention in the central parity rate, and oral intervention i.e. in response to domestic or international events that have a bearing on China's exchange rate policy China's monetary authorities intervention through oral communications to state banks about actions to be taken.

We in this thesis investigate these interventions' respective determinants, operational strategies and to what extent they are effective. Using various techniques of empirical approaches across different sub-samples, this thesis attempts to address the following research questions:

1. What are the driving forces behind Chinese monetary authorities' intervention in the foreign exchange market? In particular, given data availability, what are the determinants of Chinese central bank's intervention through purchase and sale of foreign exchange (CB intervention) in the open market?
2. Intervention in the central parity exchange rate (CPR intervention) is one of the most important form of interventions in China. What is China's decision-making process about this intervention? Once decided, what strategies that the Chinese central bank has adopted and in what situations?

3. The Chinese monetary authorities conduct interventions mainly to move the level of the exchange rate towards policy-desired direction and to main a stable and orderly condition in the foreign exchange market. To what extent China's CB intervention and CPR intervention are effective in reaching these policy objectives? In the meantime, is there any downside of intervention, despite the possible success of the intervention operations?
4. China has a special form of intervention, which is oral intervention by the authorities to state banks or foreign exchange dealers. On the external front, there is also an international dimension to this intervention, which involves international dialogues with the Chinese government about concerns with the RMB exchange rate. How effective is China's exchange rate communications to domestic agents? To what extent China's exchange rate policy is responsive to international concerns?

1.2 Main Findings and Contributions of the Research

In order to explore these questions, this thesis first explains three forms of intervention in China and constructs a measure of daily intervention. Then, using the bivariate probit approach, we test for the determinants of CB intervention based on three sets of determinants: basic, domestic and foreign exchange market determinants. We find that CB intervention follows a leaning-against-the-wind policy in the medium term, while in the short term it follows a leaning-with-the-wind strategy. In addition, the CB intervention decision takes into account volatility that exceeds the average level.

Through calculating the fair value of the RMB exchange rate, this research constructs a CPR intervention index as the proxy of CPR intervention. The results from the Bayes Tobit models show that China's CPR intervention decision is driven by market developments, international currency movements and macroeconomic conditions. The results further suggest that the objectives of China's CPR intervention change not only over time, but also between high and low interventions.

In order to test the effects of CB and CPR interventions on exchange rate levels and volatility, we employ threshold GARCH models. Using Hansen's model-based bootstrap procedure (Hansen, 1999), we find that in the whole sample period under examination there are three regimes: two regimes in the first and third sub-sample periods, and one regime in the second sub-sample period. We find evidence that CPR and CB interventions have effects on exchange rate levels but tend to increase exchange rate volatility. We also find that the effects of CPR intervention are larger than those of CB intervention. In addition, intervention frequency also turns out to be a factor affecting the performance of intervention. Results show that low-frequency intervention has effects on exchange rate levels, while high-frequency intervention can reduce exchange rate volatility.

For examining the properties and impacts of oral intervention, this research employs the event study methodology, which is considered to be good at capturing the clustered property of interventions. Oral intervention is found to impact on moving Chinese exchange rate levels in the desired direction by the monetary authorities. In addition, this research finds that while the Chinese government stands firm

publically to external pressure, the Chinese exchange rate policy exhibits noticeable flexibility in response to US calls for RMB's appreciation. Furthermore, using range-based variance, we find that successive oral interventions can reduce volatility, but single oral interventions cannot.

This research expects to make several contributions to the literature. First, we shed lights on the property and mechanics of China's intervention, which the Chinese monetary authorities have wrapped in secrecy. Based on section 2.2.3 of the literature review chapter, foreign reserves are employed as a major proxy for China's intervention. Applying a wide range of sources, this research identifies China's intervention operations including the dates, forms and strategies of the intervention. We gather newswire reports about China's interventions from one of the world's biggest news databases, Factiva, along with data from Reuters China, and the Chinese official sources such the PBOC and SAFE (State Administration of Foreign Exchange) official websites to estimate the Chinese monetary authorities' intervention action. In addition, we construct a new index as the proxy of intervention in the central parity rate.

Second, Because of very few published studies in China on the determinants of intervention, the research makes an important contribution with regard to the varying determinants and effects of China's intervention. The sample period chosen by this research is from 2005 to 2013. This represents an eventful period, because it includes two changes of the Chinese foreign exchange rate regime, the global financial crisis, and many major political changes around the global. Hence, it provides a rich context for the research, which aims at a better understanding of why

the Chinese monetary authorities intervene in the foreign exchange market, and the consequences thereof.

The third main contribution to the literature is in the application of new methodologies. Normally, the published Chinese literature would use methods such as GARCH, IV, GMM and so on. Intervention data tends to be clustered, and time-series econometric analysis of intervention is inconsistent; that is, the residuals of the reaction functions are related with the explanatory variables. Therefore, in order to get the right determinants, we use the bivariate probit model and the Bayes Tobit model. Because there exists asymmetric volatility of the RMB exchange rate series, this research applies the threshold autoregressive models, which are capable of yielding asymmetric limit cycles, to test effects of intervention on exchange rate levels and volatility. For testing the effects of oral intervention through exchange rate communications by the government, we use the event study approach.

Finally, in selecting our determinants and effects factors with regard to the process of China's intervention decision and the consequences thereof, three determinant sets are used to consider the decision on intervention through the central bank's buying and selling foreign exchange more comprehensively, while three determinants of the intervention in the central parity rate are based on the process of setting the central parity rate. Effects factors include the intervention frequency and different event criteria for testing effects of intervention on exchange rate levels and the volatility.

1.3 Overview of China's Intervention

1.3.1 Objectives of Intervention

The objectives of China's intervention are reflected in Chinese authorities' policy announcement regarding the RMB exchange rate policy. From these policy documents, we could infer what the Chinese central bank would after in pursuing its intervention operations. For instance, 21 July 2005, the PBOC, with authorization of the State Council, made announcements that the exchange rate regime is reformed by moving into a managed floating exchange rate regime based on market supply and demand with reference to a basket of currencies, and 'the RMB exchange rate will be more flexible based on market condition'²; 5 March 2008, Premier Wen Jiabao stated that the mechanism for the RMB exchange rate continued to be improved and the exchange rate elasticity was gradually raised³; 19 June 2010, PBOC continued to enhance the importance of the market forces in the exchange rate, keep the exchange rate basically stable at an adaptive and equilibrium level, and safeguard macroeconomic and financial stability⁴; 20 November 2013, based on the foreign exchange market and financial conditions, the PBOC Governor Zhou Xiaochuan announced to increase the exchange rate band gradually, enhance the exchange rate floating elasticity, and keep the exchange rate basically stable at an adaptive and

² The People's Bank of China, 21/07/2005, 'Public Announcement of the People's Bank of China on Reforming the RMB Exchange Rate Regime', <http://na.chineseembassy.org/eng/xwdt/t204468.htm>, accessed on 21 August 2016.

³ Wen Jiabao, 05/03/2008, 'Report on the Work of the Government', http://www.gov.cn/test/2009-03/16/content_1260198.htm, accessed on 04 September 2016.

⁴ The People's Bank of China, 19/06/2010, 'To Further Promote the Reform of the RMB Exchange Rate Formation Mechanism and Enhance the RMB Exchange Rate Flexibility', <http://www.pbc.gov.cn/bangongting/135485/135491/135597/1002571/index.html>, accessed on 04 September 2016.

equilibrium level⁵; 5 August 2016, the PBOC continued to make the announcements that improving the market-based mechanism for the RMB exchange rate, allowing the RMB exchange rate to float more freely, and keeping the RMB exchange rate at an appropriate and balanced level⁶.

Based on above policy documents, the target for the RMB exchange rate policy is to gradually establish a market-based and well-managed floating exchange rate system so as to safeguard macroeconomic and financial stability, and keep the RMB exchange rate basically stable at an adaptive and equilibrium level. The objectives of China's intervention are to keep the economic growth rate, the exchange rate levels close to the fundamental level and maintain the RMB exchange rate stable.

1.3.2 Forms of Intervention in China

The Chinese government has been reluctant to admit that intervention has ever occurred in the Chinese foreign exchange market, fearing that such an admission would fuel the international concerns for China's control over the RMB exchange rate. However, from an operational standpoint, there are three major ways in which the Chinese monetary authorities may intervene in the foreign exchange market:

⁵ Zhou Xiaochuan, 'Decision of the Central Committee of the Communist Party of China on Some Major Issues Concerning Comprehensively Deepening the Reform', <http://www.chinairn.com/news/20131120/11524562.html>, accessed on 04 September 2016.

⁶ The People's Bank of China, 05/08/2016, 'Q2 Monetary Policy Implementation Report', <http://www.gov.cn/shuju/2016-08/05/5097889/files/21c2e01a61c34f2b8ebf4e5e59b236f2.pdf>, accessed on 21 August 2016.

(1) The central bank intervenes by directly selling or purchasing foreign currencies in the open market. In the case of purchase intervention, the central bank trades foreign currencies with central bank notes; in selling intervention, it pours foreign reserves into the market. We term this type of intervention ‘quantity intervention’. It can also be termed as CB intervention, as it involves the central bank participating in market transactions. Only very rarely would the Chinese monetary authorities intervene through adjusting the interest rate or changing commercial banks’ required reserve rate.

(2) The central bank controls the level and growth of the RMB exchange rate by specifying the central parity and the range around which the daily trading prices are allowed to fluctuate. We call this ‘price intervention’, and it can also be termed as CPR intervention, since this intervention operation involves the setting and adjustment of the central parity exchange rate.

(3) Intervention may also take an oral form, including policy briefing, moral persuasion, formal and informal meetings, and telephone conversations. We call this ‘oral intervention’. It is straightforward for the Chinese central bank to effectuate this form of intervention by instructing or directing the attention of the state-owned banks, which are dominant forces in the Chinese foreign exchange market, towards ‘things to note’.

In what follows, Chapter 4 will concentrate on CB intervention, Chapter 5 focuses on CPR intervention, effectiveness of two forms of intervention will be examined in Chapter 6. Then Chapter 7 explores China’s oral intervention.

1.3.3 Channels of Intervention Effects

Generally, the literature has established five possible channels through which intervention may exert its effects (Sarno and Taylor, 2001; Chutasripanich and Yetman, 2015):

- (1) The monetary channel. Foreign exchange intervention can affect the exchange rate by changing money supply, interest rates and market expectation.
- (2) The portfolio balance channel. Foreign exchange intervention can affect the exchange rate by changing investors' portfolio consisting of the assets of various countries on the basis of their expected returns.
- (3) The signalling channel, also known the expectation channel. Intervention can affect the exchange rate expectations by providing the market with new relevant information.
- (4) The microstructure channel, also known the order flow channel. Intervention can affect the exchange rate by changing order flow that contains relevant information about fundamentals, market pressure or traders' expectations.
- (5) The noise trading channel, also known the coordination channel. Intervention can affect the exchange rate by changing the noise traders' future expectations.

The details for these five channels in the sector 2.1.1.

China's intervention has effects only via the noise trading channel. Because of the capital control, the interest rates cannot be flexibly changed. Therefore, the intervention cannot affect the exchange rate by the monetary channel. The portfolio balance channel is not working neither. Even there is Qualified Domestic Institutional Investor (QDII) and Qualified Foreign Institutional Investor (DFII)/Renminbi Qualified Foreign Institutional Investor (RQFII), the domestic and foreign investors still are restricted to do the investment in the Chinese foreign exchange market. In the signalling channel, it might be difficult to justify the use of secret rather than 'public' interventions (Beine and Lecourt, 2004). The China's intervention is secret. Therefore, we assume the signalling channel is hard to work in Chinese foreign exchange market. Last, the microstructure channel is based on the order flow data, and the order flow data is high frequency, which is intra daily data. Because of the data availability, we do not consider this channel. In summary, only the noise trading channel is working. Because of only one intervention channel, China's intervention has its own characters: intervention is secret, except for the oral intervention, and the forms of intervention are not only one form (3 forms).

1.4 Organization of the Study

This thesis comprises eight chapters. Following this introductory chapter, the rest of the thesis is structured as follows:

Chapter 2 provides a review of the relevant literature. In this chapter, we review the literature of foreign exchange intervention, thus offer a comprehensive survey and critical assessments relevant to the research in this thesis.

Chapter 3 introduces the evolving Chinese foreign exchange policy. In the process, this chapter provides a general introduction to the background of China's foreign exchange intervention and developments of China's foreign exchange rate regime.

Chapter 4 explores the driving forces behind China's CB intervention or the central bank's intervention through buying and selling foreign exchange. In the main, three groups of determining factors are investigated in terms of their relationship with China's decision on CB intervention.

CPR Intervention is examined in Chapter 5. In this Chapter, we propose an advanced nonlinear model to analyse the behaviour of the Chinese government's CPR intervention as reflected in the determination of the CPR intervention.

In Chapter 6, we consider the effects of CB and CPR interventions on exchange rate levels and volatility. The examination involves different aspects of intervention consequences from CB and CPR interventions.

Oral intervention and its effects are the subject matters studied by Chapter 7. This special form of intervention is conducted by the Chinese central bank through

communications with domestic units. But such intervention also has an international aspect, which involves external events concerning China's exchange rate policy. As a response, the Chinese monetary authorities may communicate to domestic traders in instructions or notes about official intentions about magnitude and direction of exchange rate changes. In the chapter, the event study methodology is deployed to detect the consequences of oral intervention.

Chapter 8 concludes the thesis. This final chapter links research findings scattered in different chapters to present an integral picture of China's official intervention in the sample period under examination. Limitations of the research and possible avenues for future research are also discussed.

Chapter 2

Literature Review

2.1 Theoretical Background

2.1.1 Main Channels

In recent decades, very many academic and policy-related studies have focused on investigating the efficiency of foreign exchange intervention in the exchange rate, a practice that began following the collapse of the Bretton Woods system. Traditional economic theory suggests that the effects of central bank intervention on exchange rate work through five main channels: the monetary channel, the portfolio balance channel, the signalling channel, the microstructure (order flow) channel and the noise trading channel (Sarno and Taylor, 2001; Chutasripanich and Yetman, 2015).

According to Galati and Melick (2002), the monetary channel works only if the foreign exchange intervention is non-sterilized. In this context, foreign exchange intervention by a central bank causes changes in the relative supplies of domestic and foreign assets, interest rates and market expectations (Edison, 1993; Sarno and Taylor, 2001), just as described in traditional monetary models.⁷ For example, if a central bank wants to depreciate the domestic currency without counteracting the

⁷ For a survey and discussion of monetary models of exchange rate determination, see Bilson and Marston (1984).

effect of higher money supply, it will purchase FX, which will lead to excess supply of domestic assets. Then, short-term interest rates will decline in the domestic money market and investors will sell assets for foreign assets. Hence, the domestic currency will depreciate. Some researchers, such as Edison (1993) and Sarno and Taylor (2001), have shown that non-sterilized intervention can affect exchange rates similarly to monetary policy by influencing money supply, interest rates and market expectation. In addition, continuing discussion about the precise effects of changes in monetary based on interest rates and interest rates change on exchange rates signals some further research into the functioning of this channel (Taylor, 1995; Borio, 1997).

Second, the theoretical literature on the portfolio balance channel, which considers that foreign and domestic assets substitute investor portfolios imperfectly, uses the framework of a portfolio balance model to analyse the effect of sterilized intervention, and assumes that investors balance their portfolio based on their expected relative returns (Branson, 1983 and 1984; Dooley and Isard, 1983; Taylor, 1995; Mongkol, 2011). Edison (1993), Taylor (1995) and Gersl (2004) build up a basic portfolio balance model to explain how the portfolio balance channel works:

$$M^D = M(i, i^* + \widehat{S}^e, W), M_i < 0, M_{i^* + \widehat{S}^e} < 0, M_W = 0$$

$$B^D = B(i, i^* + \widehat{S}^e, W), B_i > 0, B_{i^* + \widehat{S}^e} < 0, B_W > 0$$

$$B^{*D} = \frac{1}{S} B^*(i, i^* + \widehat{S}^e, W), B_i^* < 0, B_{i^* + \widehat{S}^e}^* > 0, B_W^* > 0$$

$$W \equiv M + B + SB^* \tag{2.1}$$

where S means the spot exchange rate, \widehat{S}^e denotes depreciation of the expected rate, M represents money, M^D denotes the demand for money, B and B^* are the domestic and foreign bonds respectively. The model assumes that the domestic economy is in equilibrium; that is, supplies of money and both foreign and domestic bonds equal demand. If a central bank uses foreign exchange intervention to reverse appreciation of the domestic currency, it purchases foreign bonds from private investors and sells them domestic bonds. Because the economy is in equilibrium, a rise in the supply of domestic bonds leads to a rise in the demand. If unsterilized intervention is used, there are three circumstances that could lead to the rise in demand: a rise in domestic interest rates, a depreciation of the domestic currency, and a fall in foreign interest rates. If the central bank uses sterilized intervention, interest rates will remain unchanged; in that case the exchange rate must change so that equilibrium is restored.

The third channel is the signalling channel, also called the expectation channel. Even if foreign and domestic assets could substitute perfectly, in theory the foreign exchange intervention would still have effects on the exchange rate through this channel (Mussa, 1981). Foreign exchange intervention affects exchange rate expectations by providing the market with new relevant information, under the implicit assumption that monetary authorities have superior information to other market participants and are willing to reveal that information through foreign exchange intervention (Sarno and Taylor, 2001; Inoue, 2012). In addition, in order to influence exchange rates effectively, the signalling channel requires credibility of the central bank (Dominguez and Panthaki, 2007). There are two ways in which a central bank can change market expectations: First, when the central bank considers

that the exchange rate has appreciated more than economic fundamentals justify, it will buy foreign currency, thus signalling that the exchange rate level should be lower. If market participants agree with the central bank, they will correct their expectations and lower the exchange rate by trading with the new information. Second, when a central bank wishes to depreciate the domestic currency, it will buy foreign bonds, thus signalling an intention to ease monetary policy in future, through a fall in interest rates. Because such an intervention as a signal of future monetary policy is credible, since the central bank would suffer losses if it failed to validate its signals, the market participants will change their expectations of future interest rates.

Recent studies, such as Peiers (1997), Lyons (1997 and 2001), Dominguez (2006), and Lyons and Evans (2006), use the microstructure approach to study foreign exchange intervention. They identify a new channel, named the microstructure channel, which works under the assumption of asymmetric information between informed (central banks) and uninformed traders, and in which the central bank intervenes in the foreign exchange market secretly. Empirical researches on information asymmetry are based on high frequency data. Similar to the market channel, the microstructure channel focuses on explaining the function of the foreign exchange market. Private information, institutions (trading mechanisms) and different motives of players in the foreign exchange market have relevant characteristics that influence exchange rates but cannot be explained at the same time in the traditional macroeconomic framework of exchange rate determination. Order flow takes into account relevant information about fundamentals, market pressures or market expectations that are usually not public. Peiers (1997) explains

that by working through a commercial bank, the central bank can intervene in the foreign exchange market secretly and without an official announcement. The commercial bank obtains an information advantage by receiving a market order from the central bank, and hence a short-term profit opportunity. Then it adjusts its order flows and prices. Other banks in the market learn from the order flows that an informed agent, which is the commercial bank, is in the market. That is, other traders learn relevant information regarding fundamental determinants of exchange rate. Then, in order to minimize losses, other banks will adjust their positions accordingly. However, once the information is fully received by all commercial banks, they will return to their pre-intervention trading strategies.

In order to discover whether intervention could have longer-lasting effects, Hung (1991, 1997) introduced a new transmission channel, also based on the function and the microstructure approach of the foreign exchange market, through which the central bank may affect not only the immediate exchange rate, but also the market expectations about the future exchange rate trend. The noise trading channel is under the assumption that there are two different market players in the foreign exchange market. Noise traders are chartists who often follow past trends, relying on some kind of feedback rule (buying when the price is going up, and selling when the price is going down). If the majority of traders in the FX market are noise traders, the likelihood of speculative bubbles and long-term misalignment increases. The second group of market participants are rational maximizing ‘fundamentalists’ or ‘smart money agents’, who place their investments largely according to their predicted exchange rates based on a fundamental analysis (buying when a currency is undervalued, and selling when the currency is overvalued). When noise traders

become uncertain about future exchange rate movements and question whether they have pushed the exchange rate too far, the central bank should intervene in order to give a sign, which causes the speculative traders to reverse their positions. By increasing exchange rate volatility, the central bank can manage the exchange rate. In addition, this channel offers a satisfactory explanation why monetary authorities often intervene in a thin market where chartists operate, why they intervene secretly, and why they hope (and sometimes manage) to achieve a longer lasting effect on the exchange rate.

According to an implicit or explicit international agreement of cooperation, coordinated (or concerted) foreign exchange intervention by two or more central banks occurs when they intervene simultaneously in the foreign exchange market in support of the same currency (Rogoff, 1984 and 1985; Sarno and Taylor, 2001). The rationale for international coordination of official intervention stems from the existence of significant spillover effects of domestic policies across countries. For example, under a floating exchange rate system, official intervention in one country may be expected to change the value of domestic currency with respect to other currencies, thereby affecting trading partners' economies. However, there is no persuasive empirical evidence of this channel's functioning, compared to the portfolio balance channel and the signalling channel.

2.1.2 Objectives of Intervention

This section reviews the literature relevant to the thesis, focusing particularly on the studies of determinants of foreign exchange intervention. The disintegration of the

Bretton Woods system was the first reason leading to large-scale exchange rate intervention. Then, for nearly ten years until the end of the 1980s, the monetary authorities of the Group of Five (G5) engaged in joint interventions, and many countries followed the G5 to apply intervention as a useful instrument to stabilize their own currencies. Consequently, from the 1980s in particular, central bank intervention became steadily more popular as a research area. In addition to the studies on channels of intervention, as discussed above, and especially since intervention has been more widely adopted, not least by the emerging economies, economists have become interested in examining the objectives of countries' intervention in the Forex markets.

The Plaza meeting announced that the goal of intervention was to depreciate the dollar, while the Louvre Accord added the intention to create market stability (Baillie and Osterberg, 1997). The Plaza Accord, also known as the G5 meeting, claimed that the exchange rate 'should better reflect fundamental economic conditions than has been the case'. Ito (2007) summarizes that since the Plaza Accord, monetary authorities tend to intervene when they observe that the exchange rate deviates from the level of fundamentals. In addition to this consideration, the G7 meeting, or Louvre Accord, advocated reducing excess volatility. Subsequently, the reduction of excess volatility was mentioned several times in G7 meetings: for example, in the G7 statements of 15 April 1998 and 20 February 1999 (Ito, 2007). In this context the concept of volatility is similar to that of overshooting, that is, a rapid moving away from the fundamentals followed quickly by a reversal. Therefore, from the point of view of economists, reducing volatility is a very important measure for the success of interventions.

Similar to the Jurgensen Report (1983), which studied the effectiveness of sterilized intervention in the short and long terms, Almekinders and Eijffinger (1994) argue that when central banks engage in interventions they have objectives in the short, medium and long terms. First, in the short term, ‘countering disorderly exchange market conditions’ is the common objective of all central banks. It is part of their commitment to foster a stable exchange rate regime in accordance with Article IV of the Articles of Agreement of the International Monetary Fund as amended in 1978. According to the Working Group on Exchange Market Intervention (1983) and Dudler (1988), ‘disorderly market conditions’ are indicated by large intraday exchange rate movements, a substantial widening of bid-ask spreads, ‘thin’ or highly uncertain trading, destabilizing impacts of essentially non-economic shocks, and self-sustaining exchange rate movements which may gain a momentum of their own. Then, in the medium term central banks aim to resist large short-term exchange rate movements or ‘erratic fluctuations’. In addition, they use intervention to reassess their policies and to execute ‘leaning-against-the-wind’ policy over short or longer periods. Finally, the long-term objectives focus on resisting deviation of exchange rate movements from the fundamentals (money growth, inflation, balance of payments, etc.), lessening the impact of foreign shocks on domestic monetary conditions, resisting depreciation because of its inflationary effects, and resisting appreciation in order to maintain competitiveness.

Since switching the exchange rate regime from fixed to a managed float in June 2005, the main objective of the Chinese central bank has been to keep the exchange rate stable, by trying to reach equilibrium exchange level and offsetting the

conditional volatility of the exchange rate (Xu, 2007; Zhu, 2007; Li and Chen, 2010). On 9 September, 2005, the Chinese Central Bank Governor, Mr Zhou Xiaochuan, claimed that the role of the central bank in the new exchange rate regime was that of a ‘filter’; that is, there would be no intervention in normal exchange rate movements, but the central bank would offset abnormal volatility of the exchange rate, including filtering abnormally high frequency and reducing unusually large exchange rate volatilities (Xu, 2007).

McKinnon and Schnabl (2009) argue that the expectation of further appreciation triggered by the sharp fall in US interest rates to below Chinese levels, a drop in the US Federal Funds rate from 5.25 percent in August 2007 to 2 percent in 2008, has become the core determinant of the huge accumulation of international reserves in China. To offset the liquidity from the accumulation of reserves, the Chinese central bank issues central bank bonds. These bond sales lead to monetary tightening, and interest rates tend to rise. The higher interest rates are, the more hot money is attracted. At this stage, official intervention could offset the effects of hot money.

2.1.3 Some Conceptual Issues

Sterilized Intervention vs. Non-sterilized Intervention

When a change in official foreign asset holdings occurs, monetary authorities use open market operations, such as domestic currency bills or bonds, to offset the effects of that change so that the monetary basis remains constant. This is sterilized intervention. Non-sterilized intervention, in contrast, uses the buying or selling of

foreign exchange to influence the money supply (Calvo, 1991; Mohanty and Turner, 2006; Edison et al., 2008; Lavigne, 2008). From the perspective of economists, intervention is effective in impacting the exchange rate movement only when it is not sterilized (Hung, 1997; Fatum and Hutchison, 2006; He, 2007; Disyatat, 2008). Through expanding the money supply, non-sterilized intervention leads to decrease in the interest rate. Then, the lower interest rate triggers an increase in capital inflow and decrease in capital outflow, so that the home currency depreciates. In sterilized intervention, on the other hand, through selling domestic bonds in open market operations central banks absorb the expanded money supply. As a result, the interest rate does not change and there is no policy effect on capital flows. Therefore, the typical open macroeconomic model predicts that sterilized interventions are not effective in impacting the exchange rate movement, while non-sterilized interventions are effective (Ito, 2007). However, Kumhof (2010) studies a general equilibrium monetary portfolio choice model of a small open economy and finds that sterilized interventions are effective, especially in developing countries where domestic government debt is small and fiscal spending volatility is large. The type of intervention carried out in China has shifted from non-sterilized to sterilized intervention (Xu, 2007).

Against and with the Wind

The majority of interventions take place when the exchange rate is moving in a direction the monetary authorities regard as undesirable. These interventions, applied to slow down, stop, or reverse the trend, are known as leaning-against-the-wind interventions. In contrast, interventions that lean with the wind, when the

monetary authorities intervene in the same direction as the exchange rate has been moving (Ito, 2007), happen only rarely. Because the dollar had been depreciating for several months before the Plaza Accord, that meeting is regarded as a leaning-with-the-wind intervention. In China, the monetary authorities tend to use against-the-wind intervention. In the case of RMB appreciation, the Chinese central bank purchases foreign currencies; when the RMB depreciates, the central bank sells foreign currencies (Xu, 2007).

Fear of Game Over

When the home currency depreciates sharply, the monetary authorities tend to defend its value by selling foreign currencies and purchasing the domestic currency. However, if the monetary authorities run out of foreign reserves after intervening to support the home currency, the game is over. In that case the home currency will tend to suffer freefall until it reaches the bottom (Ito, 2007). This is the reason why fixed exchange rate regimes, such as the EMS system and the Asian exchange rate regimes, have collapsed. Pontines and Rajan (2011) note that after the Asian crisis of 1997-98, emerging Asian countries tried to build up foreign reserves. However, if monetary authorities act to prevent too much appreciation by selling the home currency, there is no apparent limit to that intervention. In 2003 and 2004, China intervened substantially to sell the home currency and accumulate foreign reserves. In February 2006, China passed Japan to become the country with the largest foreign reserve holdings. According to Li and Chen (2010), there is asymmetry in Chinese intervention: the Chinese central bank uses more interventions in response to

depreciation of the exchange rate than it does in response to appreciation. China keeps a substantial foreign reserve to keep the game continuing.

2.1.3 Theoretical Underpinning

UIP

The majority of foreign exchange market studies take the uncovered interest parity (UIP) condition as their starting point (Worrell et al., 2008):

$$\Delta s_t^e = i_t - i_t^* \quad (2.2)$$

According to this equation the premium on the domestic interest rate (i_t) over the foreign interest rate (i_t^*) compensates the change in the expected spot exchange rate (Δs_t^e). If the exchange rate movements have been unchanged for a long time, the market expectation of change in the spot rate is zero, and the domestic interest rate converges to the foreign interest rate. The mechanism that drives this convergence is the inflow and outflow of finance. The market equilibrium identity is expressed as:

$$Int_t = CA_t + \Delta K_t \quad (2.3)$$

where Int_t is the amount of official intervention; CA_t represents flows generated by current account transaction, and ΔK_t is the net flow demand for domestic currency

through the capital account of the balance of payments (Sarno and Taylor, 2001). Jackman (2012) develops functions for the current account balance and the new demand for foreign currency: the price of international oil and tourism flows determine the current account balance, and interest rate spread and real estate flows are related to the net demand for foreign currency.

Central Bank Reaction Function

The development of the theoretical underpinning of determinants of intervention is a process from simplicity to complexity. In early studies, an ad hoc reaction function is usually a single equation (Edison, 1993). On the left hand side, the variable is either actual intervention or changes in foreign reserves as a proxy for intervention. Although the right hand side variables differ between researches, most studies include the changes in the exchange rate and deviations of the rate from a target level. A typical estimated equation is as follows:

$$I_t = \alpha_0 + \alpha_1(s - s^*) + \alpha_2\Delta s + \beta X + u_t \quad (2.4)$$

where I means intervention ($I > 0$ for a purchase of foreign currencies, and $I < 0$ for a sale of foreign currencies); s is the logarithm of the exchange rate; s^* is the logarithm of the target exchange rate; X is a vector of other economic variables, such as lagged intervention or money supply, and Δ is the first-difference operator. In equation (2.4), α_1 tries to capture the policy with which the monetary authorities target the exchange rate level, while α_2 is able to capture whether they lean against the wind. In the 1990s, most economists utilized not only ordinary least squares

estimates of this equation but also an instrumental-variables estimate, whereby they could allow for possible simultaneity between exchange rates and intervention (Edison, 1993).

Loss Function

Several researchers assume that the monetary authorities have a loss function of the deviation of the exchange rate from the target level (Almekinders, 1995; Sarno and Taylor, 2001). Therefore, from the central bank's viewpoint, if the exchange rate deviates from the target rate, a loss occurs and increases in a convex fashion. The loss function is assumed to be (Chen et al., 2012):

$$E_{t-1}Loss_t = E_{t-1}(s_t - s_t^*)^2 \quad (2.5)$$

where s_t is the current exchange rate; s_t^* represents the target exchange rate, and E_{t-1} is an expectation operator based on a past information set. The central bank is assumed to believe that the exchange rate should exhibit random movements if intervention is not executed, and that it is generally affected by official intervention (Ito and Yabu, 2007). Therefore, the process of exchange rate is as follows:

$$s_t = s_{t-1} + \alpha Int_t + u_t \quad (2.6)$$

where Int_t is the official intervention, and u_t is a white noise. Then, pulsing equation (2.6) into equation (2.5):

$$E_{t-1}Loss_t = E_{t-1}(s_{t-1} + \alpha Int_t + u_t - s_t^*)^2 \quad (2.7)$$

Minimizing the loss function (2.7) leads to the optimal intervention reaction function:

$$Int_t^* = -\frac{1}{\alpha}(s_{t-1} - s_t^*) \quad (2.8)$$

where Int_t^* means the optimal amount of official intervention.

DSGE

Some papers employ the Dynamic Stochastic General Equilibrium (DSGE) open economy macroeconomic model to study foreign exchange intervention operations (e.g., Ball, 1999; Lubik and Schorfheide, 2007; Bergin et al., 2007; Tovar, 2008; Gonzales and Garcia, 2010). Using the DSGE model, researchers are able to obtain results not only for the determinants of intervention, but also for the effects of intervention on the domestic economy, such as credit to households, and consumption (Moron and Winkelried, 2005; Wollmershauser, 2006; Peiris and Saxegaard, 2007; Cavoli, 2009). Focusing on the determinants of central bank intervention, Vargas et al. (2013) propose the following as a possible rule for the foreign exchange intervention:

$$\frac{q_t \gamma_t^*}{l_t} = \frac{\overline{q_t \gamma_t^*}}{l_t} - \omega(RER_t - \overline{RER}) \quad (2.9)$$

where q_t is the real exchange rate; γi_t^* represents real international reserves; l_t is loans from commercial banks; RER_t equals tradable price divided by non-tradable price, and ω measures the strength of the intervention. In addition, $\frac{q_t \gamma i_t^*}{l_t}$ and \overline{RER} are operational targets for the ratio of foreign reserves to foreign liabilities and RER_t .

According to this rule, reserves would be bought by the central bank when RER_t deviates from an operational target, \overline{RER} . Therefore, when $\omega = 0$, keeping the ratio of foreign reserves to foreign liabilities constant is the only determinant of intervention. This equation could test whether international reserves and exchange misalignment are determinants of intervention.

With regard to the conditional volatility factor, the Taylor rule is used to compare the real exchange rate figures with and without active intervention. The DSGE model includes the macro and micro levels and is very complicated. Because this research does not use it to study intervention, and the Chinese exchange rate system is distinct from the systems of other countries, the DSGE model is not explained in detail here.

2.2 Empirical Findings

2.2.1 Determinants of Intervention

In the 1990s and early 2000s, advanced countries, such as the US and Japan, often used foreign exchange intervention to impact exchange rates. Therefore, most

studies have focused on the major currencies. For instance, in order to identify the determinants of the intervention behaviour of the Reserve Bank of Australia from 1983 to 1997, Kim and Sheen (2002) test five factors: exchange rate deviations, conditional volatility of the exchange rate changes, the overnight interest rate differentials between the US and Australia, profitability of foreign exchange intervention, and inventory consideration of foreign currency reserves. Using the probit model and friction model to test which factor is the motivation of central bank intervention, they find that with the exceptions of exchange rate deviations and interest rate differentials, evidence for other factors is mixed. In general, the results of both models provide empirical support for the leaning-against-the-wind hypothesis, and the interest differential parameter has correct sign and is significant in most periods. However, as other factors in these two models are insignificant or have wrong signs in some periods, their performance is mixed.

Following the publication of intervention data by Japan's central bank in 2001, Ito made a series of efforts to work out the determinants of intervention in the Japanese foreign exchange market. First, Ito (2003) estimated a reaction function in Ordinary Least Squares (OLS) to investigate the motivation of Japanese foreign exchange intervention using daily intervention data for the period 1991 to 2001. He estimated an OLS model in which the intervention is a function of the short-run exchange rate changes (day $t-1$), the change in the yen/dollar rate in the previous 21 days, and the deviation of the current exchange rate from 125 yen/dollar. Other determinant variables, such as lag of intervention, intervention by the US Federal Reserve, and a dummy variable for a joint intervention, are also included in this model. He found that the Japanese central bank tends to use lean-against-the-wind intervention in both

the short run and the medium run, and that the more the yen/dollar exchange rate deviates from 125 yen/dollar, the more likely it is that the monetary authorities will intervene. Based on the R² bar shown in the results of the OLS model, intervention is more predictable from 1991 to the first half of 1995, while the opposite is true for the period from the second half of 1995 to 2001. Ito's (2003) study is the first attempt to analyse the effectiveness, profits and determinants of Japanese intervention after disclosure of the intervention data in 2001, but misses out one very important variable, namely exchange rate volatility. This means that the volatility effects are not analysed.

By taking into account the macro economy, Ito (2005) finds that the motivation for Japanese central bank intervention in January 2003 was to stop appreciation of the yen at a time when Japan was suffering macroeconomic and financial weakness, but intervention from October 2003 to March 2004 was to repel speculative positions rather than to stop appreciation. According to the Japanese central bank, the purposes of intervention are to make currency movement flexible, and to allow a weak economy to recover. Similar to his earlier study (Ito, 2003), he estimates a reaction function in OLS, to get the result that the central bank applies both lean-against intervention and lean-in intervention to stop appreciation of the yen: when the yen appreciates, intervention is used to prevent appreciation; when the yen depreciates, the central bank conducts intervention to further such depreciation. Another test used to evaluate intervention is tactical effectiveness. Ito (2005) explains that intervention that took place from 2003 to 2004 helped the economy to recover not because it actively depreciated the currency, but because it slowed down the speed of appreciation.

Through the application of an ordered probit model that includes political cost of intervention, Ito and Yabu (2007) find that there was a change in June 1995 from frequent small-scale interventions to infrequent large-scale interventions, and that the prevailing tendency was towards lean-against-the-wind interventions. Results of this reaction function show that both pre- and post-June 1995 yen appreciation (depreciation) led to sell (buy) intervention and that deviation of current exchange rate from the past five-year moving average triggered foreign exchange intervention. In addition, similar to Herra and Ozbay (2005), they find that lags of intervention variables are significant in both the first half (before June 1995) and the second half periods (from June 1995 to March 2001). This reflects the lower political costs of continuous intervention. Moreover, they combine the noise-to-signal method with the reaction function in order to get the optimal cut-off point. The reaction function can be a predictor of intervention, while the purpose of the optimal cut-off point is to evaluate the accuracy of prediction of intervention. The optimum cut off was higher in the first half than in the second half. This means that compared to the first half, the second half of the sample is quite unpredictable, and that reflects the intention of the Japanese authorities.

Other researchers also contribute to finding the determinants of foreign exchange intervention. Frenkel et al. (2004) employ a quantitative reaction function model, that is, the ordered probit model, to fill in the gap regarding the determinants of magnitude of central bank intervention. They use the data from the yen/US dollar market for the period 1991 to 2001, divided into two phases: 1991 to May 1995 and June 1995 to 2001. Testing whether intervention is used to decrease exchange rate

volatility and to smooth the exchange rate movements, they add the absolute deviation of the current yen/US dollar exchange rate from the 25-day moving average target variable, the daily absolute yen/US dollar returns, and one-day lagged interventions into the reaction function model. Their results suggest that a widening of the absolute band between the yen/US dollar exchange rate and the implicit target exchange rate of 125 yen/US dollar has a statistically significant effect on the probability of the Japanese central bank using large foreign exchange intervention, but that small intervention is influenced by the absolute deviation of the yen/US dollar exchange rate from its moving average. They also find that when a new director general of the Japanese International Finance Bureau was appointed in 1995, the intervention behaviour changed; that is, before 1995, the Japanese central bank conducted numerous small interventions, but after 1995 it conducted relatively large interventions.

Brandner and Grech (2005) analyse the motivation of foreign exchange intervention in the Exchange Rate Mechanism I (ERM I) by applying a censored regression model (Tobit model). ERM I is based on a multilateral target zone. It has the characteristics that: 1. All currencies are formally linked to each other through their bilateral central rates, and 2. Intervention obligations exist in a mutual way. In the multilateral target zone, unlike in a loss function, the trade-off is not primarily between intervention costs and undesired exchange rate levels, but is between the exchange rate position in the band and volatility levels. The closer the spot rate to the central parity, the higher the volatility, and vice versa. Therefore, the deviation of conditional volatility from the target volatility is the explanatory variable to analyse whether the volatility changes trigger intervention. Using daily exchange

and intervention data from 1993 to 1998, Brandner and Grech (2005) estimate a Tobit model to analyse central bank interventions in ERM I members Belgium, Denmark, France, Ireland, Portugal and Spain. In addition, they include the deviations of the exchange rate from the bilateral Deutsche mark (DEM), and of the conditional volatility from the target volatility, as independent variables, and use conditional volatility itself and lagged spot rate change as control variables. Their results show that the exchange rate position in the band (deviation from DEM central parity) significantly leads to intervention operation. However, there is less evidence that a change in market conditions (the volatility variables) induces foreign exchange intervention.

Herrera and Ozbay (2005) test the determinants of foreign exchange intervention in Turkey from 1993 to 2003 using a Tobit model and Powell's CLAD estimator. The whole data sample is divided into two sub-samples - the managed float period from 1995 to 1999, and the free float period from 2001 to 2003 - in order to compare the determinants of intervention. Results show that although the degree of persistence in interventions decreased after the change from managed float to free float, lags of intervention variables in both purchase and sale equations are statistically significant in both periods. This indicates the presence of political costs and/or a signal of future monetary policy. Results for other determinant variables show that exchange rate volatility and interest rate differential have effects on the foreign exchange intervention, but deviation from an exchange rate target has no influence. Finally, Herrera and Ozbay (2005) use Powell's CLAD estimator to test non-normality and heteroscedasticity of the Tobit model. Because the parameter estimates obtained from the Tobit and Powell's CLAD estimator are inconsistent, they find strong

evidence of non-normality and heteroscedasticity in the Tobit regression function. Their findings suggest that future investigations into the motives for foreign exchange intervention should consider the effect of non-normality and heteroscedasticity on the estimated reaction function.

Guerron (2006) uses a VAR formulation to measure the effects of sterilized interventions on the US exchange rate, and studies the motivation for foreign exchange intervention based on performance of intervention during the period 1974-2000. He finds that intervention has an effect on exchange rates in the short term and that monetary policy is the most effective way to appreciate or depreciate a currency. In addition, he adds transaction costs into the VAR model and gets the result that sterilized interventions are more effective when trading foreign bonds is more costly. Because the results of this model show that inflation and consumption change following sterilized intervention, central bank governors consider that sterilized intervention is successful, and therefore central banks will intervene in the foreign exchange markets.

Jun (2008) compares the friction model with the linear model by using daily intervention data for the Deutsche mark-US dollar market from 1987 to 1993. There is a big challenge in estimating a reaction function, in that foreign exchange intervention is infrequent. In other words, the value of intervention is zero for the majority of the observations, particularly with daily data, while explanatory variables are non-zero. Jun (2008) argues that the friction model could solve this problem, since unlike the Tobit model it considers buying and selling interventions in a single equation simultaneously. In addition, the friction model is accorded the

reasonable hypothesis that a central bank tends to intervene in a foreign exchange market when the necessity grows beyond a certain threshold. Therefore, it is assumed that the friction model should perform better than a linear model as a central bank's reaction function. However, the empirical results of Jun (2008) show opposite evidence. He uses in-sample fitting and out-of-sample forecast performance measured by RMSE (Root Mean Squared Error) and MAE (Mean Absolute Error) to compare the friction model with a linear model, using daily intervention data in the Deutsche mark-US dollar market. The friction model is found to have lower MAE but higher RMSE than the linear model in both in- and out-of-samples. Moreover, the advantage of MAE is not sufficient to offset the effects of RMSE when the average is taken with squared errors. This means that the friction model does not outperform a linear model as a central bank's regression function. The reason is that intervention decisions are at the discretion of the central bank rather than imposed by a rule.

Intervention is a complex decision process of central banks, including the determinants of intervention, the type of intervention, and the detection of foreign exchange operations by market participants (Beine et al., 2009). In order to recognize the determinants of intervention, the motivations for the government to use secret intervention, and the factors that affect the detection of foreign exchange operations by market participants, Beine et al. (2009) use a nested logit model. Explanatory variables as the determinants of intervention include exchange rate variation, exchange rate misalignment, exchange rate volatility, statements, and lagged intervention. The results for the determinants of Japanese intervention indicate that there are relationships between intervention and exchange rate

misalignment, statements, and past interventions, but that exchange rate volatility has no economically significant effect on intervention. In addition, they find that the Japanese central bank prefers to use secret, rather than public, intervention. Furthermore, large interventions are more easily detected than small interventions, so a central bank has to face a trade-off over the size of its interventions. Finally, the results suggest that the various determinants of the intervention process interact strongly.

Hall and Kim (2009) study on-shore (Tokyo) and off-shore (London and New York) market developments to investigate the intervention reaction function of the Japanese central bank during the period 1991 to 2004. They divide a 24-hour trading day into two parts: 7:00am to 5:00pm Japanese Standard Time is the period of on-shore trading hours, and 5:00pm to 7:00am Japanese Standard Time refers to the off-shore trading hours. They use friction models to test determinants of central bank intervention in three phases, namely Pre-Sakakibara (prior to June 1995), Sakakibara (June 1995 to Dec 2002), and Recent Period (Jan 2003 to Mar 2004). The determinants of intervention considered are exchange rate deviations, exchange rate volatility, one-month covered interest arbitrage transaction cost band, which is a broad measure of market disorderliness, and lagged intervention. The major findings of this study (Hall and Kim, 2009) are that prior to 1995, previous day's intra-daily yen return was significant, and the lagged intervention was another motivation for intervention; but during June 1995 to Dec 2002, the Japanese central bank also reacted to overnight off-shore market returns. Furthermore, the central bank responded only to the one-month covered interest arbitrage transaction cost band in the overnight London markets. In all samples, the exchange rate volatility is

found to be a major determinant of intervention decisions. Moreover, Hall and Kim (2009) find evidence that during the period 2003 to 2004 yen depreciations triggered secret leaning-into-the-wind intervention.

In recent years, as intervention operations have become much more common in emerging markets, a growing number of studies have analysed the determinants of intervention in those markets. Unlike the results of Kim and Sheen (2002), evidence gained by Akinci et al. (2006) proves that the main motivation of central bank intervention is to reduce the excessive volatility of exchange rate changes. They focus on an emerging market, the Turkish economy, under an inflation targeting framework during the period 2001 to 2003. A probit model and Granger causality tests are used to seek out the determinants of central bank intervention in Turkey; in addition, Granger causality tests are employed to test the effectiveness of the signalling channel. The results show that the main purpose of central bank intervention is to reduce the excessive volatility of exchange rate changes, but the leaning-against-the-wind hypothesis is not supported. Furthermore, Akinci et al. also find that the signalling channel is not completely supported in Turkey, and that there exists a positive relation between the interest rate and currency depreciation.

Brause (2008) applies rolling estimation frameworks to obtain the changing intervention dynamics. There are two approaches in the empirical methodology to studying the motivation and effectiveness of intervention in Argentina from 2003 to 2008, namely, a rolling reaction function (OLS model) and a rolling GARCH model. The OLS model unravels time-varying motives for central bank intervention, while the rolling GARCH model evaluates the effectiveness of central bank intervention.

Estimation results of the rolling reaction function comprise global results, which use the whole sample, and time-varying results, which apply charts to show the time-dependent variation of intervention motivations. In the global results, the target level result is odd, and the overnight interest rate differentials coefficients have wrong signs, but conditional volatility has significant effect on daily central bank intervention. Time-varying results, however, are contrary to the global results. Specifically, in the time-varying results, target level and overnight interest rate differentials impact on central bank intervention significantly, but the conditional volatility shows a perverse result. Brause (2008) explains these contradictory results in terms of time-varying motives, and concludes that long-run and exchange rate target perspectives were given more importance than short-run and volatility issues. Finally, Brause (2008) proves that economic and monetary policy fundamentals can explain motive and impact effects.

Using daily Turkish foreign exchange intervention data for the period 1993 to 2006, Ozlu and Prokhorov (2008) employ an m-regime threshold model that focuses on the determinants of intervention in order to analyse whether foreign exchange intervention supports the policy of the Central Bank of the Republic of Turkey. They divide intervention data into two sub-periods based on the exchange rate regimes: the managed float period from 1995 to 1999, and the free float period from 2001 to 2006. In the managed float period, based on the evidence of heteroscedasticity in the results, they find no support for a threshold in the reaction function. In addition, the linear model shows that the deviation from the 22-day moving average is a significant determinant of intervention. This is consistent with the exchange rate policy during the managed float period, which was based on the idea of applying

exchange rates to control inflation. In the free float period, they reject the linear model in favour of the two-regime model. In the high volatility regime, excess volatility is more significant than deviation from the trend to trigger intervention. This is consistent with the announced goal to lower excess volatility. Finally, lagged interventions can influence future intervention in both regimes.

Detected structural breaks in the exchange rate and the intervention series are important in Loiseau-Aslanidi's (2011) study of the intervention motives and effectiveness of the National Bank of Georgia. The paper uses unique daily data from the National Bank of Georgia to research the determinants and the effectiveness of sterilized intervention during the period from 1996 to 2007. In order to figure out the determinants of intervention, daily central bank reaction functions are estimated by ordinary least squares (OLS) with lagged variables and by the instrumental variables (IV) approach. In these models, Loiseau-Aslanidi (2011) considers the structural breaks that are detected. The breaks happened because of the Russian financial crisis in 1998, and the National Bank of Georgia responded by changing the exchange rate regime from fixed to free-floating. The main results of Loiseau-Aslanidi's (2011) paper are that these breaks are significant for intervention motives and effectiveness. In order to smooth the exchange rate movements, the National Bank of Georgia uses lean-against-the-wind intervention.

Using daily intervention data for Barbados during the period 2003 to 2011, Jackman (2012) estimates a dynamic complementary log-log model that associates oil price shocks, tourism, interest rate spreads and real estate inflows with foreign exchange intervention. The foreign exchange market in Barbados uses a pegged exchange rate

system. Because the Central Bank of Barbados does not publish the intervention data, Jackman (2012) applies the total of foreign currencies to replace intervention. The results show that intervention tends to be persistent over consecutive days; that is, lags of intervention have significant effects on the current intervention. The reason is that there are pressures tending to peg the exchange rate in subsequent days. In addition, the results show that seasonal movements of tourism and interest rate spreads are reasons for sale intervention, but do not influence purchase intervention, and that an influx of real estate flows is likely to affect the probability of a purchase intervention, but might have limited impact on the marginal tendency of a sale intervention. Moreover, oil price shock is the only exogenous variable that is likely to affect both sale and purchase interventions.

Using weekly data from the Peru central bank during the period January 2001 to December 2010, Ventura and Rodriguez (2015) apply count data models to determine factors that influence intervention decisions. Count models include the Poisson Regression Model (PRM), the Negative Binomial Regression Model (NBRM) and the Zero Inflated Model (ZIM). Results of these models provide evidence that the deviations of the exchange rate from its long-term trend, previous week's intervention, the Embig spread, differentials between foreign and domestic interest rate, and the spread between prime corporate and interbank interest rates, are economically significant determinants. The Embig spread is an indicator for country risk, and the spread between prime corporate and interbank interest rates is the devaluation expectations indicator. In their paper, Ventura and Rodriguez (2015) consider determinants of both purchase intervention and sale intervention. The results show that foreign exchange sales can be predicted more accurately, but

prediction of foreign exchange purchases is less precise. This implies that there are other determinants that cannot be included in models for foreign exchange purchases, such as reducing exchange rate volatility or accumulating international reserves.

2.2.2 Effects of Intervention

A number of studies test the effects of central bank intervention on the level and the volatility of exchange rate based on the five transmission channels. Because results depend on the types of intervention, model assumptions, and the time periods and exchange rates studied, they are widely conflicting. Edison (1993), Dominguez and Frenkel (1993), Sarno and Taylor (2001) and Neely (2005) provide detailed surveys of the literature about the effects of intervention. According to the Jurgensen Report (Jurgensen, 1983), the first study to test the effects of intervention on exchange rate, in the early 1980s there was broad acceptance among academics and economists that the effects of intervention were economically significant only in the very short term.

The empirical research on intervention transmission channels finds mixed results. For instance, with regard to the portfolio balance effects, Ghosh (1992) uses monthly data of US dollar-German mark rate from 1980 to 1988, and finds that there is statistically significant portfolio influence on the exchange rate. However, Huang (2007) uses a probit model to get evidence that the portfolio channel does not work in practice. Similarly, following the release of daily data on intervention by the US authorities in the early 1990s, the strand of empirical literature studying the significance of the signalling channel grew rapidly, and again the findings are

inconsistent. For example, using weekly American data from February 1977 to February 1981, Dominguez (1987) finds a positive relationship between intervention and money supply surprises during periods when the monetary authorities have high credibility and reputation; Lewis (1995) finds that the foreign exchange intervention can change future monetary policy and that changes of monetary policy might induce leaning-against-the-wind intervention, while Catte et al. (1994) extract 17 short-term periods of definite intervention by studying the signalling channel. However, some empirical studies argue against a relationship between sterilized intervention and monetary policy. Although Kaminsky and Lewis (1996) find that US central bank intervention might sometimes signal monetary policy, their results are against the direction predicted by the conventional signalling hypothesis; no evidence is found for the effect of foreign exchange intervention on the exchange rate, and the intervention raised exchange rate volatility during the studied periods (Bonser-Neal and Tanner, 1996; Galati and Melick, 1999).

Some studies test the effects of foreign exchange intervention without considering the transmission channel. After the late 1980s, direct approaches, such as multivariate GARCH frameworks, became popular to test the effects of foreign exchange intervention on the level and volatility of exchange rate. Using newly released official data from the Japanese Ministry of Finance for the period April 1991 to March 2001, Ito (2002) studies Japanese foreign exchange intervention effects on the level of the exchange rate. He examines the effects of the Japanese foreign exchange intervention from various angles: First, reviewing the history of the yen/dollar movement and Japanese foreign exchange intervention during the 1990s, he finds that the intervention strategy used by Sakakibara seemed totally different

from that of his predecessors. Second, he finds that during the period under study, by buying the dollar low and selling it high, the Japanese monetary authorities produced large profits in terms of realized capital gains, unrealized capital gains, and carrying (interest rate differential) profits; these profits amounted to 9 trillion yen over the decade. Third, the GARCH regression results indicate that intervention operations in Japan during the second half of the 1990s produced the intended effects on the yen. This result suggests that large, infrequent interventions are more effective than small, frequent interventions. Furthermore, joint interventions are proved to be 20-50 times more effective than unilateral Japanese interventions. However, Ito (2002) does not consider volatility effects.

Disyatat and Galati (2007) apply the instrumental variable (IV) approach to study the impact of foreign exchange intervention on the mean and conditional volatility of the exchange rate in the Czech exchange market during the period September 2001-October 2002, using daily intervention data. They focus on the effect of intervention on the level of exchange rate, the conditional volatility and risk reversals (i.e. the bias of market participants with regard to the exchange rate of the much weaker koruna against the much stronger euro). In the IV approach, the reaction function for the Czech foreign exchange intervention is used as an instrument. The results show that foreign exchange intervention has weak statistically significant impact on the spot rate and the risk reversal, but this impact is small. In addition, they find that the Czech monetary authorities intervene in the exchange rate when the speed of koruna appreciation accelerates. This shows that the portfolio balance channel and the microstructure channel are more likely to have been effective in emerging market economies than in industrial countries, and also

that compared with a depreciation of the domestic currency, an appreciation has more impact on exchange rate in emerging market economies.

In order to identify the efficacy of foreign exchange intervention, Kearns and Rigobon (2005) estimate Generalized Method of Moments (GMM) models using daily intervention data from Australia and Japan in the periods from July 1986 to November 1993 and May 1991 to June 2002 respectively. Through analysing the frequency and amount of foreign exchange intervention, they find the dates on which changes occur (i.e. the monetary authorities decide to decrease small interventions and concentrate on big ones) in the Australian and Japanese policy regimes, and use a novel identification assumption: by including a change in policy regime in the GMM model they are able to estimate the contemporaneous effect of foreign exchange intervention. Their results analysed by GMM models show that estimates of the effect of foreign exchange intervention are statistically and economically significant and have the correct signs for both the Japanese and Australian foreign exchange markets. In addition, they find that a USD 100 million purchase of Australian dollars by the Reserve Bank of Australia would be related to an appreciation of 1.3-1.8%, while a purchase of the same amount of yen by the Bank of Japan would appreciate the yen by only 0.2%. Furthermore, the largest effect on the exchange rate happens on the day it is conducted, while there are smaller effects on subsequent days. Finally, they find that both central banks tend to lean against the wind.

Hillebrand et al. (2009) examine the relation between foreign exchange intervention by the Bank of Japan, and return and realized volatility of the yen/dollar exchange

rate. The sample period is from April 1991 to October 2004, during which they identify two structural breaks: In June 1995 the Japanese central bank changed the intervention strategy from frequent small interventions to infrequent large interventions (Ito and Yabu, 2004), while in April 1998 there was broad deregulation of the foreign exchange market, causing a change in conditional volatility (Ito and Melvin, 1999). Through estimating a simultaneous equations model (i.e. GMM approach), Hillebrand et al. (2009) find that Japanese foreign exchange intervention was unsuccessful during the period 1991-1995. The coefficient for return of yen/dollar exchange rate is negatively significant, and foreign exchange intervention is associated with an increase in volatility. During the period 1995-1998, Japanese foreign intervention could move the yen/dollar exchange rate in the desired direction, but the study does not find evidence of successful influence on volatility. During the period 1998-2004, there is strong evidence of a decrease in volatility, while return of yen/dollar exchange rate is not influenced by Japanese foreign exchange intervention. Most of the results are robust when considering other financial variables, unrestricted vector autoregressions, and alternative change-points.

Kurihara (2013) studies the effects of Japanese foreign exchange intervention on the yen/US dollar exchange rate using the sample period 19 March, 2001 to 31 December, 2012. Unlike previous studies, Kurihara (2013) takes both market communication and sterilized intervention into account. In order to analyse the effects of the portfolio balance channel, signalling channel and communication channel on exchange rate, he applies the OLS and GMM approaches. The empirical results show that foreign exchange intervention has effective impact on the Japanese foreign exchange market. Because the past exchange rate is important to affect the

movement of the spot exchange rate, the signalling effect exists. However, the portfolio balance channel and the communication channel do not have effects on the Japanese foreign exchange market. This is because the model for the portfolio balance channel does not fit well in the real world, and exchange rate control is not the objective of the Bank of Japan. Furthermore, the results from the OLS and GMM models indicate that the Bank of Japan uses foreign exchange intervention to prevent too much appreciation of the yen, to promote exports, and to expand the economy.

In recent years, some studies have adopted the event study approach to test the effects of foreign exchange intervention on exchange rate. For example, Fatum (2008) studies daily effects of Bank of Canada intervention on the CAD/USD exchange rate during the period 1 January, 1995-30 September, 1998. By analysing three criteria for successful intervention, namely 'direction', 'smoothing', and 'volatility', Fatum (2008) finds that foreign exchange intervention is systematically related with both a change in the direction and a smoothing of the exchange rate. However, there is no evidence that Bank of Canada intervention has effect to reduce the volatility of the CAD/USD exchange rate. The results also show that the effects of foreign exchange intervention are weakened when adjusting for general currency co-movements against the USD. In addition, using unique data on whether intervention operations were discretionary or carried out according to a mechanistic policy framework, Fatum (2008) is able to compare the effects of these two types of foreign exchange interventions. The success-to-failure ratios associated with mechanistic events are very similar to those related with discretionary events, suggesting that discretionary Canadian foreign exchange interventions are not more effective than mechanistic interventions.

Leon and Williams (2012) study the effects of intervention on the foreign exchange market using unique daily data for the Dominican Republic, covering 1997-2005. A matched-sample test of equality of means before and after intervention events is applied to judge the success of foreign exchange intervention based on three criteria, in this case ‘direction’, ‘reversal’, and ‘smoothing’. Unlike Fatum (2008), Leon and Williams (2012) do not consider volatility, but focus solely on the level of the peso/US dollar exchange rate. Their results show that foreign exchange intervention in the small open economy is effective in the short run when measured against the direction, reversal and smoothing criteria. Furthermore, these results, which are robust to alternative event-window definitions and to alternative criteria for measuring success, suggest that the monetary authorities follow a policy of ‘leaning against the wind’, aimed at either smoothing the exchange rate or reversing its trend direction. In addition, ‘fear of floating’ is found to be present in the Dominican foreign exchange intervention; that is, the foreign exchange intervention acts against strong appreciations which could conflict with the central bank’s objective of ensuring competitiveness. The results also imply that interventions could be an effective policy tool in emerging market economies in order to maintain export competitiveness while containing imported inflation.

Echavarría et al. (2013) use an event study approach to compare the impacts of different types of foreign exchange intervention for the Colombian case during the period 2000-2012. Following Fatum and Hutchison (2003), they define four criteria to evaluate a successful intervention, namely ‘direction’, ‘reversal’, ‘smoothing’, and ‘matching’. Applying four types of interventions (international reserve

accumulation options, volatility options and discretionary interventions), they obtain evidence that all types of foreign exchange interventions have been successful according to the smoothing criterion. Furthermore, when considering the four criteria, volatility options seem to have had the strongest effect. Through using different window sizes and counterfactuals, they find that the results are robust.

Using the daily Japanese foreign exchange intervention data for the period from April 1991 to December 2005, Hoshikawa (2008) examines the effects of central bank intervention frequency on the foreign exchange market. The conjecture effect of intervention frequency on exchange rate volatility and on exchange rate level is estimated using the GARCH methodology, specifically GARCH (1,1) and EGARCH estimation. Japanese central bank intervention is described by differences in frequency: there are high and low frequency intervention periods. Hoshikawa's (2008) empirical results imply that there are two different effects according to the frequency of intervention. First, high frequency intervention stabilizes the exchange rate by decreasing exchange rate volatility. Second, compared to the high frequency intervention, low frequency intervention has a larger effect on the exchange rate level. This suggests that the Japanese monetary authority has two policy objectives, one with regard to exchange rate level and one related to exchange rate volatility. If the authority's objective is to reduce exchange rate volatility, it may implement foreign exchange intervention with high frequency; on the other hand, if the objective is to change the exchange rate level, the authority may intervene with low frequency.

Utsunomiya (2013) also uses the daily Japanese foreign exchange intervention data to test the effect of intervention frequency on the yen/dollar market from April 1991 to December 2005. Unlike Hoshikawa (2008), Utsunomiya (2013) considers periods of nonlinearity, which cannot be captured by standard volatility models such as the GARCH model. He modifies the original target zone model of Krugman to characterize the dynamic behaviour of an exchange rate. In addition, in order to determine the existence of threshold nonlinearity in the mean of the yen/dollar rate return, Utsunomiya (2013) applies the Threshold Autoregressive (TAR) model, and the results suggest that threshold nonlinearity exists in the yen/dollar rate. A Double Threshold GARCH (DTGARCH) model is used to consider the threshold effect of foreign exchange intervention frequency on exchange rate. In common with Hoshikawa (2008), Utsunomiya (2013) finds that high frequency intervention stabilizes the exchange rate by decreasing exchange rate volatility, but the effect of intervention frequency in Hoshikawa (2008) is underestimated, as the presence of asymmetry is ignored. The results of the DTGARCH model show that when analysing the effect of intervention frequency, considering the threshold effect is important. In addition, Utsunomiya (2013) finds that high-frequency interventions reduce exchange rate volatility more strongly when the yen appreciates.

Suardi (2008) uses the DTGARCH model to study the effects of Japanese intervention and US intervention from 1991 to 2003. He finds that interventions by the Bank of Japan and the Federal Reserve are more effective in changing the direction of the exchange rate movement and reducing its volatility level in a regime in which the exchange rates are severely misaligned. There is also evidence that in such a regime a negative return of exchange rate elicits higher levels of volatility

than a positive return of equal magnitude. In addition, the presence of asymmetric volatility in exchange rate returns may be a result of active central bank intervention.

2.2.3 Literature on Intervention in China

Chinese Studies on Theories of Foreign Exchange Intervention before 2000

Following the Asian financial crisis of 1997, foreign exchange intervention became a hot topic. Against the background of the RMB becoming fully convertible for current account transactions in 1996, Huang's (1997) research of central bank intervention in China established the basic framework for studying this topic. His study includes the provision, purpose, necessity and technique of foreign exchange intervention, and specifies the two kinds of intervention, that is, non-sterilized and sterilized intervention. Huang (1997) finds that both non-sterilized and sterilized interventions are effective, but the latter can change the relative money supply of two countries. He concludes that intervention has a long-term influence on the exchange rate.

Jiang (1999) analyses the relation between the openness of the financial market and the development of the short-term money market in China, and concludes that the central bank's monetary operations are an important guarantee to allow the RMB to be freely convertible. Lu (1999) focuses on testing the effectiveness of foreign exchange intervention and summarizes theories of non-sterilized and sterilized intervention. Through studying the methods of Chinese official intervention, he

finds that in order to improve regulation, the Chinese central bank should adjust the elasticity and flexibility of the money supply by recycling loans.

Empirical Studies on Foreign Exchange Intervention

Since 2000, the Chinese literature has used econometric theories to examine foreign exchange intervention. The main strand of research has focused on the efficiency of Chinese foreign exchange intervention. With the exception of a few studies of intervention in other countries carried out to find useful advice for China, the majority of the research has tested whether or not the Chinese central bank intervention is effective.

Zhu (2003) reviews the literature on the definition and measurement of exchange market pressure, and derives equations to test exchange market pressure and calculate a central bank intervention index. Using quarterly data for the 1994-2002 period and simultaneous equations estimated by the two-stage least squares method, Zhu (2003) calculates the Chinese exchange market pressure and central intervention index, and discusses the movements of RMB exchange market pressure, the effectiveness of foreign exchange intervention, and the applicability of simultaneous equations.

Guo (2007) studies the efficiency of PBOC sterilized intervention by using re-loan, rediscount, deposit-reserve ratio, and open market operation to replace the foreign exchange intervention. He applies the quarterly data from 1996 to 2007 to regress the variables of the PBOC's domestic and foreign assets, GDP, and the government

deficit. The regression results indicate that sterilized intervention is efficient in China.

Gui (2008) analyses monthly data from 2004 to 2006, to test the efficiency of the portfolio channel and the signalling channel in China. She uses international reserves to replace foreign exchange intervention. The results show that the portfolio channel is efficient, but only in the short term, and that foreign exchange intervention can signal future monetary policy.

Following Roper and Turnovsky (1980) and Devereux (1999), Pu (2009) estimates an optimal intervention function (IS-LM model) to test the Chinese quarterly data from 1996 to 2008. By comparing the actual intervention operation with the optimal intervention, he analyses the problems that exist in Chinese intervention: first, with the exception of the time periods from the fourth quarter of 2003 to the first quarter of 2008, and from the first quarter of 1998 to the fourth quarter of 1998, the direction of intervention is opposite to the direction of optimal intervention; second, the magnitude of actual intervention is dramatically larger than that of optimal intervention, especially during the Asian financial crisis (1997-1998) and after 2007.

Liang and Mo (2013) apply the VAR model and Johansen cointegration test to analyse the effectiveness of Chinese intervention after adding the Non-Deliverable Forward (NDF) variable, which is an RMB exchange rate forecasts variable. Through studying the monthly data from 2004 to 2011, they find that with the addition of this variable, the intervention is effective in the portfolio channel.

Wang (2013) uses the monthly Chinese intervention data from 2002 to 2011 and applies an event analysis approach to study the effectiveness of intervention. Results show that the intervention is effective, but the effectiveness is asymmetric; that is, selling the US dollar to support RMB appreciation is more effective than is purchasing the US dollar to support RMB depreciation.

Recent Developments in Intervention Research in the Chinese Literature

In recent years, the research on Chinese foreign exchange intervention has developed in a number of interesting directions. First, Chinese studies are using a variety of financial instruments to study foreign exchange intervention. In their research on the effectiveness of central bank intervention, Gan et al. (2007) conclude the usefulness of the event study method. Using China data, they find that the effect of intervention to stop RMB depreciation (dollar appreciation) is greater than the effect to stop RMB appreciation (dollar depreciation).

Second, the Chinese literature is using new exchange rate theories to study exchange intervention. For example, Xu (2006) uses microstructure theories, while Xie et al. (2008) investigate the effect of central bank intervention on the exchange rate market by assessing the relation between foreign exchange intervention and changes of monetary policy. Based on the assumption that central banks hold insider information and speculators hold private information, many studies use a GARCH model to reflect market participants' analysis of information using net speculative positions (change) data. The results of this literature do not support the signalling channel, because the movements of intervention in the exchange rate market have

the opposite direction to the anticipation of the central bank, and the past net speculative positions can make intervention happen.

Third, the Chinese literature discusses the cost and benefit of foreign exchange intervention and open market operations of intervention. Wu (2005) studies the effectiveness of sterilized intervention on monetary policy, and concludes that in the short term, sterilized intervention is effective in terms of controlling inflation and absorbing foreign exchange reserves, but over the long term, the effect of sterilized intervention is not significant. Zeng (2005) argues that there is hedging cost when the Chinese central bank issues central bank bills and at the same time purchases US treasury bills, because the interest rate of US treasury bills is lower than the interest rate of central bank bills. The use of central bank bills to hedge foreign exchange reserves cannot achieve the dual goals of stable exchange rate and the avoidance of inflation.

The extant literature tends to first focus on advanced economies, and then on the emerging markets. Studies on the Chinese foreign exchange intervention are even fewer. Similarly, the literature on intervention channels is almost exclusively focused on the mature markets, leaving a considerable research gap in the field involving the channels through which foreign exchange intervention take place in emerging markets.

Particularly in the Chinese case, studies on the country's intervention are mostly concentrated on the effects of official intervention on exchange rate movements.

Determinants of China's intervention is under-researched and little studies are there

on oral intervention. Research on the intervention channels in relation to China is almost total absent in the literature, internationally or in the Chinese domestic discourse.

Chapter 3

Background to China's Exchange Rate Policy

This chapter introduces the background to China's exchange rate policy. The reasons for focusing on the Chinese case are that first, China's exchange rate regime has experienced important changes in recent years. This gives us an opportunity to investigate into the varying determinants as well as the effects thereof in the whole sample and in different sub-samples. The second reason is related to the existence of the central parity rate and the exchange rate band, whose operation and economic significance are challenging to the current academic thinking and policy design. We could study the CPR intervention which is a new form of intervention. The last reason is that there is very little literature on China's intervention. It's a very under-researched area whereas new contributions to the literature by the research could be significant. It is divided into three parts. First, it presents an overview of the regime shifts of the foreign exchange system to date. Then, it describes statistical features of RMB exchange rate movements. Finally, this chapter reviews the developments of financial liberalization of China's foreign exchange market and China's Foreign Exchange Trading System.

3.1 An Overview of China's Exchange Rate Policy

3.1.1 Regime Shift before 2005

Over the last few decades, China has changed from being a self-sufficient economy to become the world's second largest economy. As a result, especially since the country's entry into the WTO in 2001, China's trading system and exchange rate regime have received growing attention.

From 1949 to the 1970s, under a planned economy, China maintained a fixed exchange rate at a highly overvalued level, due to an import-reducing strategy to decrease its dependence on other economies (Peterson Institute for International Economics, 2009). During that period, the official rate played an insignificant role in foreign trade. Because of the strong government control over the money market, the CNY was almost inconvertible. The overvaluation of the RMB resulted in a lack of incentive for domestic foreign trade companies, as the exchange rate was significantly lower than the price they received on the international market, and for each transaction, the company would incur a loss if it attempted to convert the earnings into renminbi. During this period China 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 et al., 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. Following the reform that took place in 1978, the initial fixed exchange rate was detrimental to the export incentive, indicating that the role of exchange rate had changed. In 1980, the State Council introduced an 'internal settlement rate' (close to the average cost of earning one USD

in exports, RMB 2.8 to USD) to be used in trade transactions instead of the official rate (RMB 1.5 to USD). This arrangement continued until 1984.

Following abolition of the internal settlement rate, multiple exchange rates appeared in the market once again. China maintained a dual exchange rate system. The period from 1985 to 1993 saw the emergence of regional swap markets (called Foreign Exchange Adjustment Centres), where foreign-funded firms could swap foreign exchange among themselves (Mehran et al., 1996). During this period, increasing amounts of corruption generated further market distortions.

The crucial change came in 1994 with the establishment of the national foreign exchange market, which formally phased out the official rate (Xu, 2000). On January 1, 1994, the government moved the official rate to the prevailing swap market rate (RMB 8.7 to USD), so unifying the official and swap market rates (Truman, 2008). China adopted the managed float regime with a narrow band. This reform process was disrupted by the outbreak of the Asian financial crisis, which caused China to become cautious against excessive exchange rate fluctuations. Increasingly the Chinese currency was pegged to the US dollar. However, the Chinese authorities repeatedly stated their commitment to allowing more flexibility to the exchange rate arrangements. In addition, by the end of 1996, the RMB had become fully convertible for current account transactions. This measure helped to make domestic prices more flexible and more closely linked with world prices. Over the following 18 months the government revalued the currency until the exchange rate reached RMB 8.30 to the USD in June 1995, and then slowly appreciated to RMB 8.28 in October 1997. Indeed, between 1994 and 2001, the RMB steadily appreciated, apart

from during the East Asian Financial Crisis in 1997-1998, during which time China resisted depreciation in line with the other Asian currencies (receiving much praise at the time for helping to maintain stability in the region). Subsequently, the nominal value of currency versus the US dollar fluctuated in a very narrow range around RMB 8.28 until the exchange rate regime reform was initiated on July 21, 2005.

From 1997 until July 2005, the RMB was effectively pegged to the US dollar at the rate of 8.28 RMB/dollar. On July 21, 2005, China's exchange rate regime underwent a major change. The PBOC announced not only a 2.1 percent appreciation of RMB against USD, moving the official bilateral rate from RMB 8.28 to RMB 8.11, but also that the Chinese exchange rate would be administered as a managed float rather than as a pegged regime (PBOC, 2005). The July 2005 announcement heralded two important changes: (a) the Chinese currency would be managed 'with reference to a basket of currencies' rather than being pegged to the US dollar; and (b) the exchange rate movements would be 'more flexible', with the value of exchange rate based more on 'market supply and demand' (Goldstein and Lardy, 2009). The details of exchange rate regime shifts from July 21, 2005 until today are explained in the next section.

3.1.2 Regime Shifts in Recent Years

The currency regime introduced in China in July 2005 ended a decade-long fixed nominal exchange rate, and caused immediate revaluation of the exchange rate from RMB 8.28 to RMB 8.11 against the dollar. Moreover, the government announced that the Chinese currency would be managed 'with reference to a basket of

currencies' instead of being pegged to the USD. Therefore, under the new regime the exchange rate would be more flexible, since the value of the RMB would depend on market supply and demand rather than the official settlement. These two important changes indicate that the first objective of the PBOC is to stabilize exchange rate movements.

As explained above, the exchange rate was now to be influenced not only by the US dollar, but by a basket of foreign currencies. On August 9, 2005, in a speech marking the opening of the Shanghai central bank's headquarters, Central Bank Governor Zhou Xiaochuan (2005) announced a list of 11 currencies to be included in the reference basket. He stated that the US dollar, euro, yen and Korean won would be the major currencies. Alongside these would be British sterling, the Singapore dollar, Russian rouble, Malaysian ringgit, Australian dollar, Canadian dollar, and Thai baht. The governor explained that these currencies had been chosen as the economies of their respective countries were important for China's current account. However, in July, 2008, as a response to the global financial crisis, the PBOC once again pegged the RMB to the US dollar, and abandoned the managed float regime. This situation lasted for about a year and half, until June, 2010. After that date, the Chinese exchange rate regime changed back to the managed float, and the RMB exchange rate fluctuated from RMB 6.84 to RMB 6.14.

An important aspect of the change to a managed float regime was that exchange rate movements would be more flexible. In July 2005, the PBOC set a fluctuation limit of 0.3 percent per day (in either direction) for the RMB against the dollar (*vis-à-vis* the central parity). From May 21, 2007, the PBOC extended the fluctuation limit

from ± 0.3 percent to ± 0.5 percent. However, during the period July 22, 2008 to June 21, 2010, the band was abandoned, because the RMB again pegged to the US dollar. Then, after June 21, 2010, the band was re-launched at ± 0.5 percent. On April 16, 2012, the State Administration of Foreign Exchange (SAFE) announced that the USD/CNY bid and ask price could fluctuate by a maximum of 2 percent around the central parity rate. The band became 4% on March 17, 2014. As a result of the policy aimed at achieving more flexible exchange rate movements, over the last eight years the RMB exchange rate has become more fluctuating. The details of the exchange rate movements are explained in the next section.

In order to make the RMB exchange rate more subject to influence by market forces, the PBOC improved the central parity rate setting process, and on August 11, 2015 the central parity rate changed from 6.2097 to 6.2298. The improved CPR setting process is based on the closing rate of the interbank foreign exchange market on the previous day, supply and demand in the market, price movement of major currencies, and daily central parity quotes from the market makers as reported to the China Foreign Exchange Trade System (CFETS). The IMF described this reform as ‘a welcome step’ that allows market forces to have a greater role in determining the exchange rate.

On November 30, 2015, the International Monetary Fund (IMF) decided that the renminbi (10.92%) would be added to the Special Drawing Rights (SDR) basket, effective from October 1, 2016.

December 11, 2015 saw publication of the CFETS RMB exchange rate index. It closed at 101.45, having gained 1.45% since the end of 2014. In order to observe the different aspects of RMB real effective exchange rate changes, the CFETS calculates this index based on the BIS basket and the SDR basket, which closed on that date at 102.28 and 99.52 respectively, having gained 2.28 and lost 0.48% respectively since the end of 2014.

3.2 Statistical Features of RMB Exchange Rate Movements

Figure 3.1 shows the RMB/US dollar exchange rate daily movement from 22 July, 2005 to 22 January, 2016. The figure shows five stages in the movement of the RMB exchange rate. First, from 2005 to July 2008, there is a trend of sharp appreciation of RMB. As discussed in section 3.1, before the change to the exchange rate system in 2005 the Chinese government had depressed the exchange rate level, and subsequently sought to find the equilibrium RMB exchange rate. This explains the sharp appreciation trend. Second, from July 2008 to June 2010 the RMB exchange rate was stable. This is explained by the fact that during this period, because of the global financial crisis, the RMB was fixed to the US dollar. Third, from June 2010 to January 2014 the RMB appreciated slowly. On 21 June 2010, the PBOC began to implement a new ‘managed floating’ exchange rate policy (PBOC, 2010).⁸ The RMB exchange rate started to fluctuate, and the main market viewpoint was that it should appreciate. In addition, during this stage, the PBOC again tried to find the RMB exchange rate equilibrium level. From February 2014 to July 2015, the PBOC

⁸ On 19 June 2010 (Saturday), the PBOC announced that the RMB exchange rate would follow a ‘managed floating’ regime with reference to a basket of currencies (PBOC, 2010).

continued to increase the influence of market forces on the RMB exchange rate. The movements of the exchange rate fluctuated up and down, not just to one side. The final stage is from August 2015 to the present, during which period the PBOC has implemented deeper reform of China's exchange rate system, in order to make it meet the standards of the SDR.

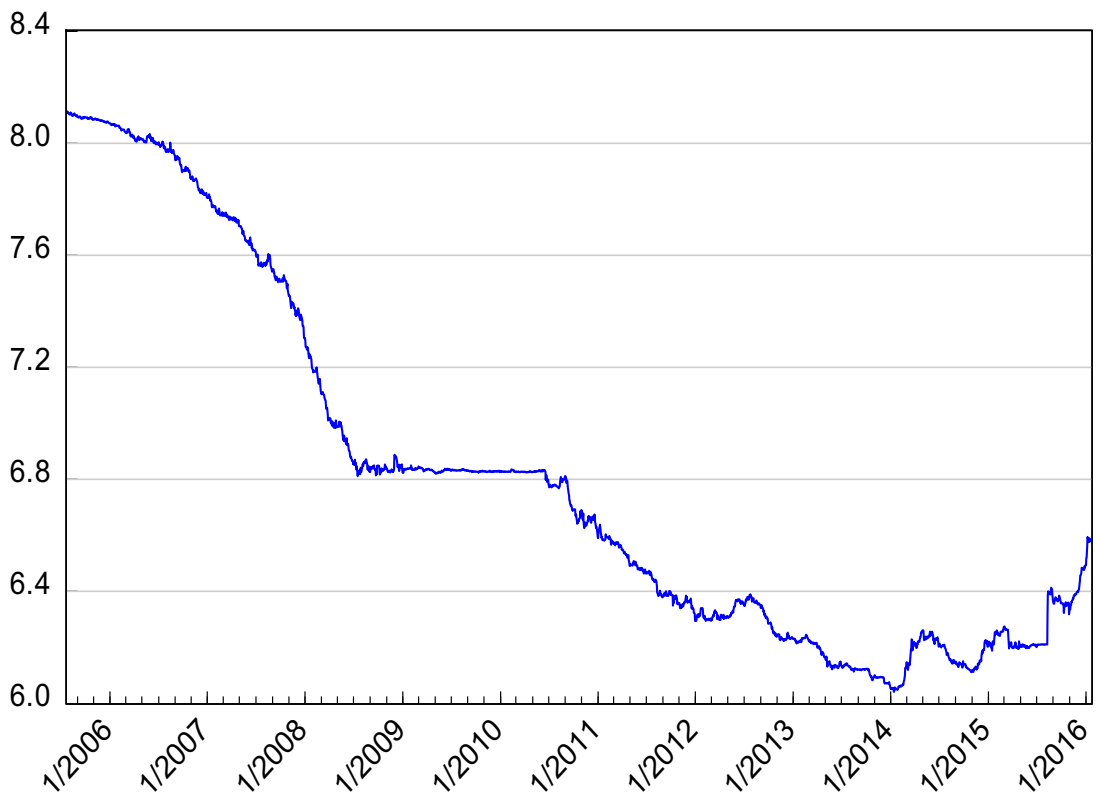


Figure 3.1 Daily RMB/US Dollar Exchange Rate, July 2005 - January 2016, Last Price

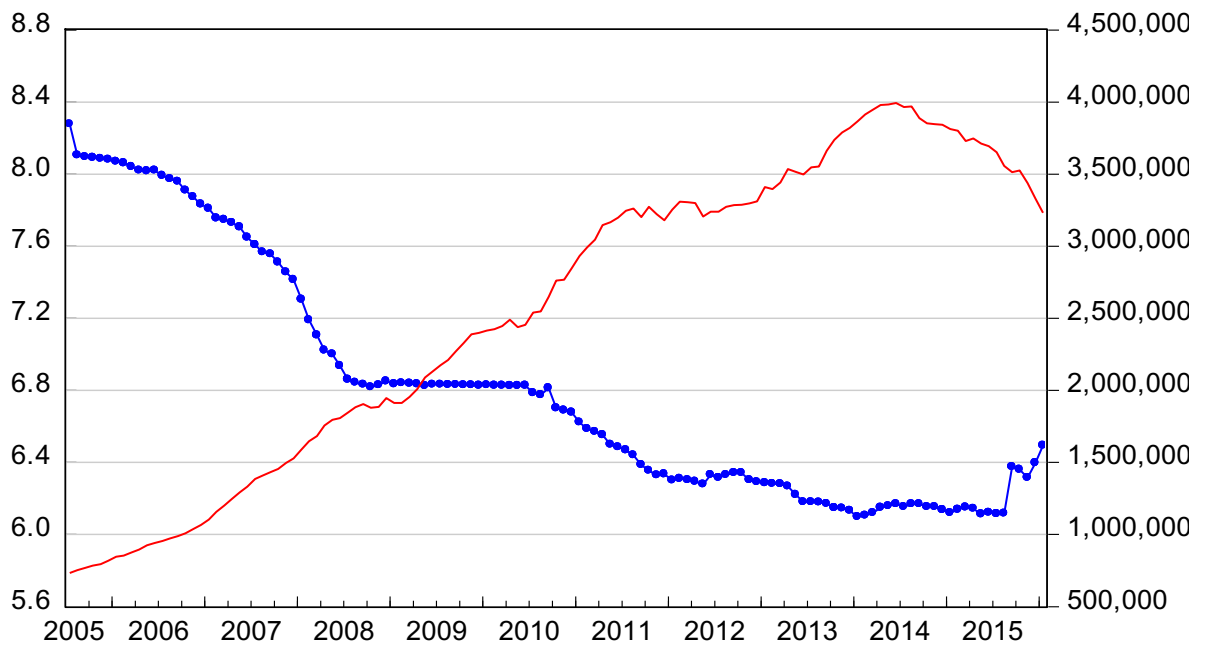


Figure 3.2 Monthly RMB/US Dollar Exchange Rate (with dot) and China Foreign Exchange Reserves (Billions), July 2005 - December 2015

Figure 3.2 shows the relation between the RMB exchange rate price (the dot line) and the monthly changes of foreign exchange reserves (the straight line). From the figure, we can see that the foreign exchange reserves were built up rapidly during the period 2005 to June 2014. However, this situation was reversed after June 2014. Because some economists use foreign exchange reserves as a proxy of intervention data (Sarno and Taylor, 2001), the increase of China's foreign exchange reserves could indicate that the PBOC applied intervention to affect the exchange rate frequently during this period. Particularly in the financial crisis period, foreign exchange reserves increased rapidly, but exchange rate movements were fairly stable. This suggests that the PBOC might have used large-scale interventions during these years.

3.3 Developments of Financial Liberalization and China's Foreign Exchange Trading System

The China spot foreign exchange markets are interbank (interdealer) markets, where authorized members can trade spot foreign currencies with other members in the CFETS. The 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 1.5% above or below this CPR. 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 members' 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.

3.3.1 Financial Liberalization Development

With the reforms, the Chinese foreign exchange market gradually became 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 a part of the central bank, i.e. the People's Bank of China (PBOC).

In 1978, the foreign exchange retention system was set up. This allowed domestic exporters to retain a certain portion of their foreign exchange earnings, based on the quotas specified by government. The retained foreign exchange earnings could be used to import goods and services. Two years later, in 1980, the BOC established trading facilities for foreign exchange retention quotas in Beijing, Tianjin, Shanghai and Guangzhou. Authorized domestic enterprises were able to transfer their quotas to other domestic enterprises at a negotiated price. At the same time, the State Council introduced the RMB internal settlement rate for trade (ISR), effective from January 1, 1981. The ISR was set at RMB 2.8 per USD, while the official rate at that time was 1.53 per USD, implying an 83% devaluation for RMB. Foreigners could get the official rate with their foreign exchange certificates (FECs).

Although the ISR was an important means to devalue the overvalued official exchange rate, Lin (1997) shows that it was not really determined by market forces. In December 1984, the PBOC announced the abolition of the ISR and the official RMB exchange rate was devalued to RMB 2.8 per USD. The second round of foreign exchange reform took place in 1984. In April of that year, in order to encourage foreign investment, the Chinese government opened up major coastal areas. While the previous reform had sought to decentralize foreign trade

management, this second round was intended to lessen government controls over foreign trade enterprises, thus bringing about trade liberalization.

Financial liberalization was also beginning. 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. The swap exchange rate was 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 individual investors to participate in the swap market transactions. In 1993, the number of foreign exchange swap centres increased to 108, and swap transactions accounted for 80% of China's total external transactions, compared with 50% in 1991 (Lardy, 1993; Zhang, 2001c). On April 4, 1994, an interbank market known as the China Foreign Exchange Trading System (CFETS) was established in Shanghai, and the previous swap centres were transformed into local branches of the CFETS, linked to the Shanghai centre through a nationally integrated electronic network.

3.3.2 The Current Trading System

The China Foreign Exchange Trading System (CFETS) is the interbank trading and foreign exchange division of China's central bank, under the administration of the People's Bank of China (PBOC) and the State Administration of Foreign Exchange

(SAFE). Its 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, and information services for foreign exchange, bond and money markets. The fundamental guideline for its functioning is 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 *China Money* went into publication in October 2001. FX deposit brokering debuted in June 2002, and in June 2003 the paper quotation system was established. In May 2005, interbank trading of 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.

The CFETS headquarters are in Shanghai, while there is a back-up centre in Beijing. There are 18 sub-centres throughout the country, in Shenzhen, Tianjin, Guangzhou,

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 cooperatives, 1056 corporate pension funds and 88 social security funds. Its affiliated institution, the Interbank Lending Market, has a total membership of 955.

3.4 Summary

Comparing with other countries' interventions, there are two characteristics of China's intervention that stands out. First, China's intervention takes place alongside with several important changes in China's exchange rate regime. After 2005, China's exchange rate regime experienced further changes including the changes in the band width. Second, the Chinese government is a heavy interventionist and tend to intervene the market quite often and in large scales. In advanced countries, such as Japan, interventions would not happen in this high frequency. In addition, China's intervention operations would take place in a complicate range of form, which makes China's intervention an interesting case to study.

This chapter has introduced the general background of China's foreign exchange market, including its evolution, trading system, movements of the exchange rate, financial liberalization and international reserves. The main topics discussed in this thesis are all based on this background.

Chapter 4

Determination of Central Bank Intervention in China: Evidence from the Yuan/Dollar Market

4.1 Introduction

Intervention in the foreign exchange market is an essential tool, widely used by central banks to direct domestic currencies to a desirable level or to stabilize the currencies' movements (Sarno and Taylor, 2001). In recent years, as intervention operations have become much less common in advanced markets, researchers have paid growing attention to interventions in the emerging market economies, where this tool is now used extensively. According to a survey by Menkhoff (2013), official intervention in these economies takes various subtle forms, and is an increasingly important force in international monetary relations.

China is prominent among the emerging economies as an extensive user of intervention, to significant effect. However, despite great international concern and global repercussions, there is a surprising lack of studies of China's foreign exchange intervention, especially the factors that drive the intervention decision. This thesis aspires to help fill this gap, and to achieve a better understanding of China's exchange rate policy.

This chapter contributes to the literature in several ways. First, we identify the dates of Chinese CB intervention. Central banks tend to operate foreign exchange intervention secretly, and this is especially so for China. In the Chinese context, intervention is commonly referred to as ‘exchange rate management’. Many secret foreign exchange activities would be hidden under the name of ‘management’. In the absence of specific intervention data, studies of foreign exchange intervention face the significant challenge of how to identify the dates and forms of intervention. This study makes a critical contribution to the literature by using a wide range of media reports to identify the dates and forms of Chinese secret intervention.

Second, our sample period covers 8 years, from 22 July, 2005 to 22 July, 2013, which provides a good opportunity window to observe evolving practice of Chinese intervention, including during the global financial crisis period. During this sample period, the Chinese exchange rate regime shifted twice. On 22 July, 2005 when the exchange reform was launched, China shifted from the dollar peg to a managed floating rate regime. However, this process was disrupted by the breakout of the global financial crisis, and the RMB regime reverted to the dollar peg around July 2008. When the crisis eased, it moved back to the managed floating system in June 2010.

We test the determinants of Chinese intervention operations for the whole sample and for the financial crisis sub-sample using 3 determinant sets: basic determinants, domestic market determinants and foreign exchange market determinants. The basic determinants comprise the medium-term and short-term exchange rate deviations

from the trend, conditional volatility, and lags of intervention; the domestic market determinants are the stock index and the volatility dummy variables; the foreign exchange market determinants are interest rate differentials, deviations from the central parity, the reserves ratio and foreign direct investment (FDI) flows. Identification of deviations from the central parity and the FDI flows as the determining factors is the novel feature of this chapter. In addition, through estimating the bivariate probit model, this chapter further investigates which determinant factors can influence purchase and sale interventions, respectively.

We find evidence that medium-term deviations are an important influence on the adoption of leaning-against-the-wind intervention, but short-term deviations are in line with the leaning-with-the-wind hypothesis. We perform a further analysis of the exchange rate volatility, studying its effects on the days when the RMB exchange rate volatility exceeds its average level and when the yuan is appreciating or depreciating. It is found that conditional volatility can trigger intervention. In addition, in purchase intervention decisions the Chinese central bank, the People's Bank of China (PBOC), considers a wide range of factors, such as national economic conditions, inventory imperatives, and FDI flows. However, in sale intervention decisions, the PBOC's main consideration is the central parity deviations.

The rest of this chapter is organized as follows. Section 4.2 reviews the related literature. Section 4.3 introduces China's exchange rate policy in the sample period and identifies the country's intervention dates. Section 4.4 describes the data and variables deployed in the study. Section 4.5 estimates the bivariate probit models. The results are reported in Section 4.6. Section 4.7 presents the main findings.

4.2 Related Literature

Central banks' intervention in currency markets is generally motivated by the intention to move the exchange rate to a desired level and to promote market stability (Baille and Osterberg, 1997). Almekinders and Eijffinger (1994) suggest a finer classification of the intervention objectives. In the short run, central banks commonly operate to 'counter disorderly exchange market conditions' (Dudler, 1988). Then, in the medium term, they aim to resist large short-term exchange rate movements or 'erratic fluctuations'. Their long-term objectives focus on resisting deviations from fundamentals, lessening the impacts of foreign shocks on domestic monetary conditions, and avoiding undesirable impacts of currency depreciation or appreciation.

One of the chief concerns of empirical research in this field involves the main drivers behind government intervention. Jurgensen (1983) was among the first to study the link between long- and short-run exchange rate deviations and sterilized intervention. He found that only short-run exchange rate deviations affect sterilized intervention. Following the publication of intervention data by the Japanese monetary authorities, Ito (2002) proves that deviations of the current exchange rate from the short-run (day $t-1$) and medium-run (21 days) trend rates, and from 125 yen/US dollar have effects on intervention in Japan, and that the Japanese monetary authorities tend to use lean-against-the-wind intervention. Based on the results of this research, Ito and Yabu (2007) find that in addition to the day $t-1$ deviation and the previous 21 days' deviation, the past five-year moving average of deviations is another determinant of

intervention in Japan. However, Herrera and Ozbay (2005) and Beine et al. (2009) do not find significant effects of such deviations.

Brander and Grech (2005) study the influence of conditional volatility on the intervention decision. They use a GARCH model to find the conditional volatility for participants in Europe's Exchange Rate Mechanism I (ERM I), i.e. Belgium, Denmark, France, Ireland, Portugal and Spain. Their results show that the resulting relation between intervention and conditional volatility differs between markets. Using absolute returns of the yen/US dollar exchange rate as a measure of conditional volatility, Frenkel et al. (2004) find that volatility can affect the intervention decision. However, estimating a multinomial logit model and a nested logit model, Beine et al. (2009) find that the Japanese central bank does not take volatility into consideration when making decisions on intervention. Galati et al. (2006) and Ito (2007) also obtain evidence that volatility is not a determinant of intervention.

Because of the nonlinearity in the intervention data, OLS estimates of central banks' intervention are inconsistent (Jun, 2008; Hall and Kim, 2009; Chen et al., 2012). In order to overcome this problem, researchers apply probit models in their intervention study. Kim and Sheen (2002) develop a probit model to investigate the working of five determining factors behind Australian intervention: exchange rate trend deviations, conditional volatility, interest rate differentials, profitability, and inventory imperatives. Their results show that three of these five factors have significant effects on intervention; the exceptions are profitability and the inventory factor. Akinci et al. (2006) also apply the probit model to study the determinants of

intervention in the Turkish economy. Similar to the Japanese results from Baillie and Osterberg (1997), they find evidence that, in the Turkish context, the main motivation of the official intervention is to reduce the excessive volatility, and hence the leaning-against-the-wind hypothesis is not supported. Frenkel et al. (2004) estimate magnitude of central bank intervention and test its determinants in an ordered probit model. Their results suggest that deviations from the target level of 125 yen/US dollar are statistically significant for large foreign exchange intervention, but small-scale intervention is influenced by the deviation from the previous 25 days' moving average. Ito and Yabu (2007) improve the specification of this class of ordered probit models by incorporating the political cost of intervention. They find that lags of the intervention variable are significant in the model, reflecting the lower political costs of continuous intervention.

Among recent studies on intervention in emerging market economies, Loiseau-Aslanidi (2011) considers the Georgian foreign exchange market by using squared changes in the exchange rate as a measurement of volatility. The findings indicate that volatility can trigger intervention. Jackman (2012) tests the Barbadian foreign exchange market and gets evidence that higher interest rate spreads may reduce sale intervention, but do not trigger purchase intervention. Similar research has been conducted for other emerging or developing economies, such as Turkey (Akinci et al., 2006; Herrera and Ozbay, 2005), Argentina (Brause, 2008) and Pakistan (Mehdi et al., 2012). Research focusing directly on the Chinese official intervention has started to emerge only recently. The main contributors to this sparse literature are Chinese economists in domestic forums, with an overwhelming focus on the effects

of official intervention (Lu, 1999; He, 2007; Xie et al., 2008; Liang and Mo, 2013; Wang, 2013).

4.3 Official Central Bank Intervention in China and its Measurement

4.3.1 Evolution of the RMB Exchange Rate Regime in Recent Years

The currency regime introduced by China in July 2005 ended a decade-long fixed exchange rate system. In a policy statement at that time, the Chinese central bank announced that the RMB would be managed ‘with reference to a basket of currencies’ instead of being pegged to the US dollar. Henceforth, the renminbi exchange rate would be allowed to fluctuate within a narrow margin around a base rate known as the central parity rate. As a result, the exchange value of the RMB would come under the influences of market supply and demand.

Under this managed floating rate regime, the RMB exchange rate is no longer determined solely by the US dollar, but also by the movements of a basket of international currencies. According to Governor Zhou Xiaochuan (2005), the reference basket contains 11 currencies, with the US dollar, the euro, Japanese yen and Korean won being the first-tier heavy weights. The other currencies comprise the pound sterling, the Singapore dollar, Russian rouble, Malaysian ringgit, Australian dollar, Canadian dollar, and Thai baht. The currencies’ weights in the basket are chosen according to their respective importance in China’s external trade.

However, when the global financial crisis hit, the dollar peg was reinstated unofficially. This situation lasted for about a year and half, until June 19, 2010. On that date, the Chinese central bank issued a statement indicating that it would ‘proceed further with reform of the RMB exchange rate regime and increase the RMB exchange rate flexibility’. Since then, the Chinese exchange rate regime has reverted to the managed float system based on market supply and demand with reference to a basket of foreign currencies.

When the managed floating rate system was first introduced, the daily trading price of the US dollar against the RMB was allowed to fluctuate within a narrow 0.3% band around the central parity. On May 18, 2007 this band was expanded to 0.5%, and then on April 14, 2012 it was expanded yet further, to 1.0%. On April 16, 2012, the State Administration of Foreign Exchange (SAFE) announced that, in the interbank foreign exchange market, the bid-ask spread of the daily trading price of the US dollar against the RMB would fluctuate by a maximum of 2% around the central parity rate. As a result, the RMB exchange rate has shown a steady increase in flexibility.

4.3.2 Measures of Central Bank Intervention

This chapter concentrates on the CB intervention. To measure the CB intervention in China, we identify the dates on which the Chinese central bank has stepped into the foreign exchange market to conduct intervention; these dates are our proxy for the intervention. Following the method of Beine et al. (2009), we search the news media for PBOC intervention operations as reported by market traders and analysts.

More specifically, we scrutinize the newswire reports on the PBOC in Factiva and Reuters China. We deploy two basic rules: First, when it is reported that direct central bank intervention has occurred, we mark that day as a CB intervention day. If the Chinese monetary authorities are reported to have purchased (sold) the foreign currency (e.g. the USD), that day is designated as +1 (-1), and 0 otherwise. Second, when there is reporting of CB intervention via the state banks (indirect purchase or sale of foreign exchange), we also mark this as a CB intervention day and the sign of such intervention is marked the same as above. The CB intervention information at all degrees of certainty, including likely, clearly, covert, suspected, think, may have, and rumour, is counted in determining the dates of Chinese official intervention.

For the purpose of illustration, on 10/11/2012, news reports indicate that, believing the RMB exchange rate to have appreciated sufficiently, state banks including the Industrial and Commercial Bank of China and the Agricultural Bank of China started to buy the USD, which pushed up the dollar price near the closing time of the market. Four traders in the market viewed this event as reflecting central bank intervention. Therefore, we mark this date as +1 of CB intervention. In another instance, on 29/09/2011, because the USD index increased sharply, traders expected that depreciation of the RMB exchange rate would intensify. However, the state banks acted against the market expectation by selling the USD at the market closing time, which was interpreted by market participants as an intervention reflecting the central bank's desire to keep the exchange rate stable. We therefore sign this date as -1 of CB intervention.

Table 4.1 shows that during the whole sample period the central bank engaged in purchase or sale of foreign currency on 661 trading days. Further analysis reveals that the PBOC does not use intervention only to address RMB appreciation, since if that were the case the number of purchase interventions would be significantly greater than the number of sales interventions (now 371 versus 290). Rather, the main intention of the PBOC seems to be to stabilize the exchange rate movements and offset abnormal exchange rate volatility.

Figure 4.1 displays the official intervention in the sub-sample periods. From the figure, we can observe that compared to purchase intervention, sale intervention is an auxiliary tool to adjust the exchange rate movements. The number of purchase interventions is generally greater than that of sales interventions both in the normal period (319 versus 258) and during the financial crisis (52 versus 32). This difference indicates that the PBOC was more concerned regarding appreciation than depreciation at all times, not just during the financial crisis.

Collecting intervention information from news reports is an important way of getting the CB intervention data. Because the Chinese CB intervention is secret and so is little known in the literature, construction of the intervention data in this regard represents a further contribution of this thesis to the literature. On the down side, the limitation in our approach to the construction of CB intervention is that we do not have a reliable way to gauge the quantity of China's official intervention.

Table 4.1 Official Chinese Interventions: 22 July 2005 - 22 July 2013

	Obs.	Mean	Std. dev.	Skewness	Excess Kurtosis
Total intervention	661	0.0388	0.5658	0.0116	3.1557
Purchase intervention	371	0.1778	0.3824	1.6857	3.8415
Sale intervention	290	-0.139	0.3460	-2.0876	5.3579

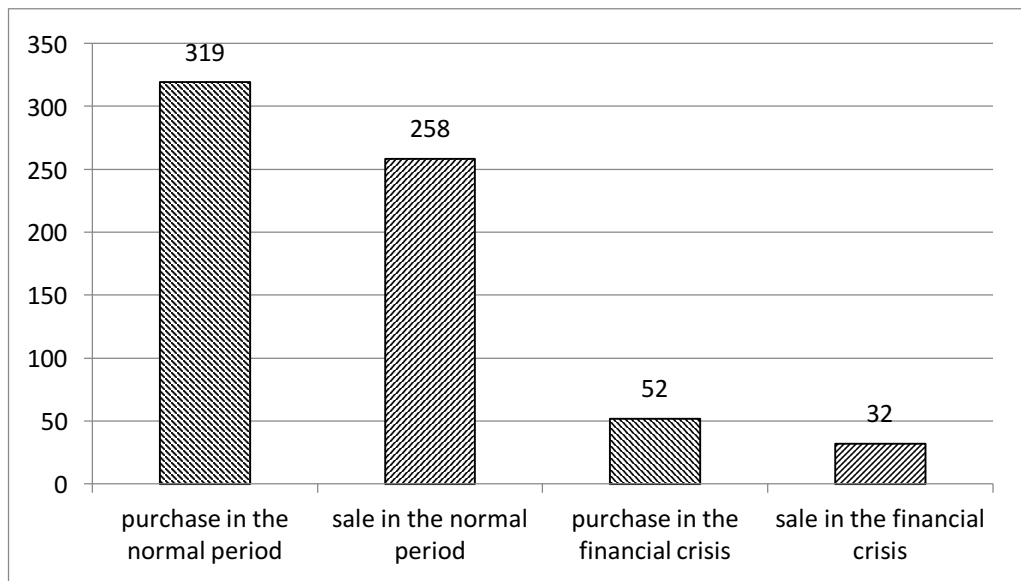


Figure 4.1 Official Interventions in the Sub-Sample Periods

Notes: The financial crisis period is defined as from 15 July, 2008 - 23 June, 2010; the rest of the sample is the normal period.

4.4 Data and Variables

4.4.1 The Dataset

To empirically examine the determinants of intervention in China, we use a daily time series dataset covering 8 years, from 22 July, 2005 to 22 July, 2013. Based on information from newswire reports provided by Factiva and Reuters China, the

whole sample period has a total of 2087 trading days, excluding official holidays. To further understand the determinants of China's intervention, we additionally divide the whole sample into two sub-samples: the financial crisis period from 15 July, 2008 to 23 June, 2010, and all the rest of the sample, which is classified as the normal period. From Figure 4.2, it can be seen that the movements of the RMB exchange rate were flat from 15 July, 2008 to 23 June, 2010 when, in response to the global financial crisis, China re-pegged its currency. We also use the $\sup_{\gamma}(F(\gamma))$ test (Andrews, 1993) to check robustness of the finding that the structural break dates are 15 July, 2008 and 23 June, 2010. The F-statistic at each break candidate (γ) can be obtained by the standard Chow test. From Figure 4.3, it can be seen that the largest (4.86) F-statistic is in July 2008. While the second largest (3.63) F-statistic is in September 2010, I still choose June 2010 (2.73), because this coincides with the PBOC announcement of the change of China's exchange rate regime from pegged to a managed float. We reject the null hypothesis that there is no break at 5% significance. Therefore, 15 July, 2008 and 23 June, 2010 are the structural break dates.

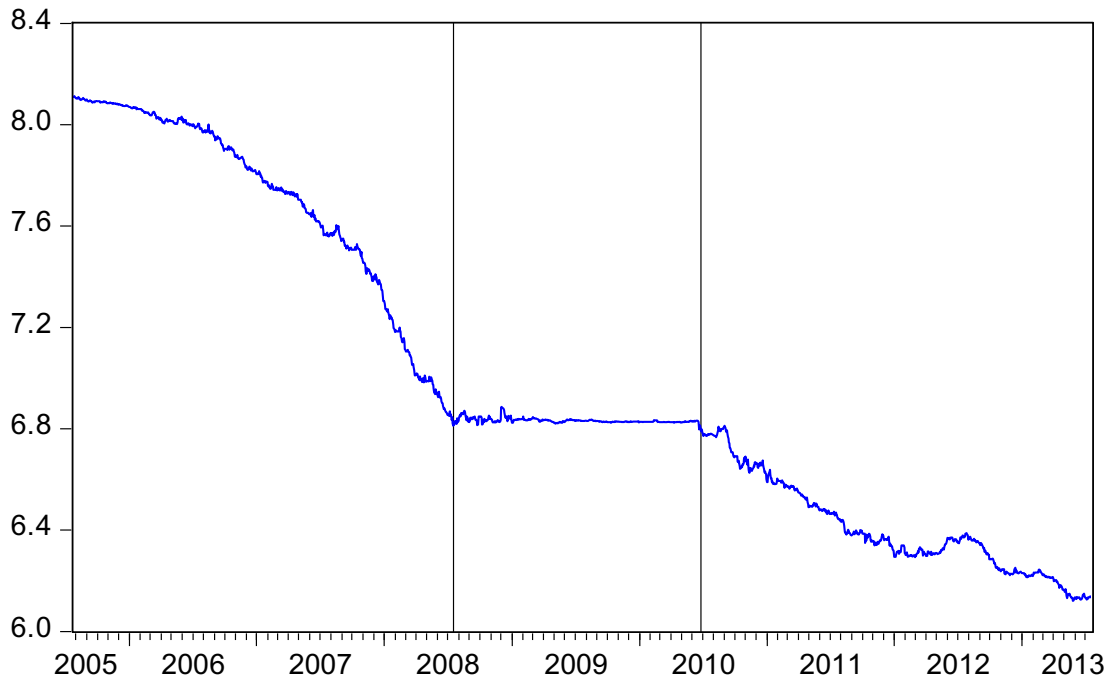


Figure 4.2 Movements of the USD/CNY Exchange Rate

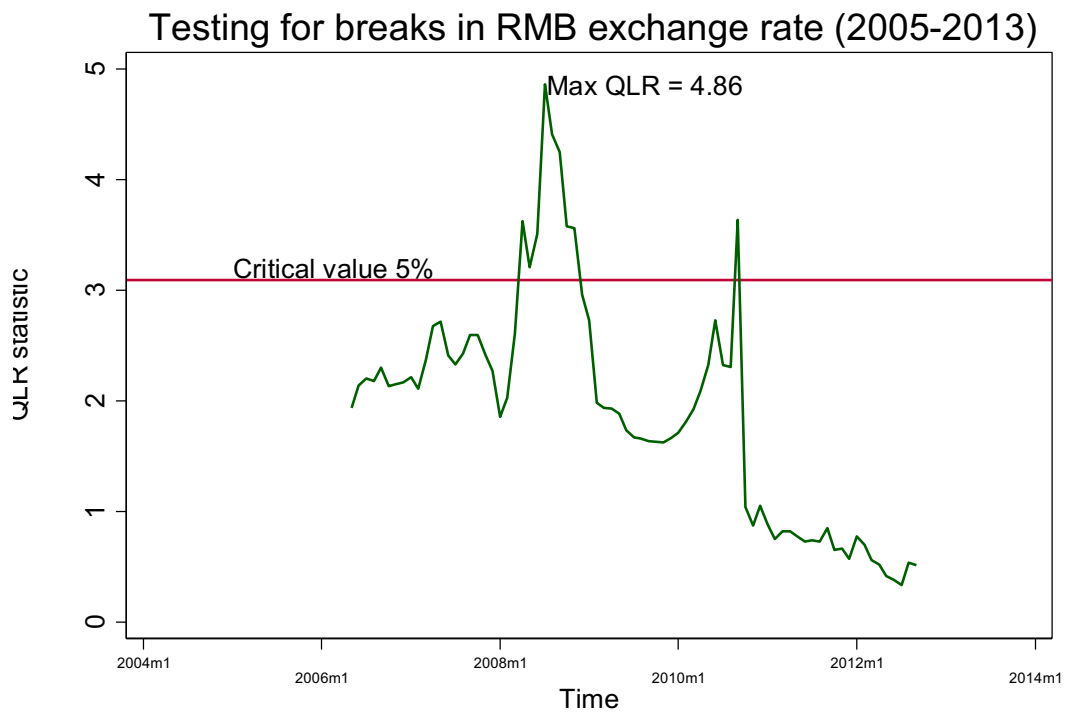


Figure 4.3 F-Test Statistic for Break

4.4.2 Basic Determinants

Trend Deviations from Targets

Following Chen et al. (2012), our intervention determinants include two target exchange rates: the previous week's exchange rate as the short-term target, and the previous month's moving average rate as the medium-term target. Deviations from the targets are calculated as follows:

$$\text{Short-term deviation: } SDEV_t = s_{t-1} - \frac{1}{5} \sum_{i=1}^5 s_{t-1-i} \quad (4.1)$$

$$\text{Medium-term deviation: } MDEV_t = s_{t-1} - \frac{1}{21} \sum_{i=1}^{21} s_{t-1-i} \quad (4.2)$$

It is reasonable to expect that a positive/negative deviation, or an appreciation/depreciation of the RMB exchange rate, would induce a purchase/sale intervention by the PBOC to stabilize the currency. For instance, in the case of a RMB appreciation relative to the US dollar, the PBOC would lean against the wind by engaging in a purchase intervention, i.e. purchasing the US dollar.

Conditional Volatility

According to Hsieh (1989), Baillie and Bollerslev (1989), Kim (1998), and Akinci et al. (2006), GARCH (1,1) models with Student-t distribution are helpful to estimate the conditional volatility of daily exchange rate changes. In this study, a GARCH (1,1) model is deployed to estimate conditional variance for the whole sample period. The model is specified as follows:

$$\Delta s_t = \beta_0 + \beta_1 \Delta s_{t-1} + \beta_2 \Delta s_{t-2} + \beta_3 Interest_t + \beta_4 GB_t + \beta_5 Int_{p,s,t-1} + \varepsilon_t \quad (4.3)$$

$$h_t = \alpha_0 + \alpha_1 h_{t-1} + \alpha_2 \varepsilon_{t-1}^2 + \alpha_3 Interest_t + \alpha_4 GB_t + \alpha_5 Int_{p,s,t-1} \quad (4.4)$$

where Δs_t is the log difference of the USD/CNY exchange rate. $Interest_t$ represents the Shibor (Shanghai interbank) offer rate. This variable is used to account for the relation between the exchange rate and the interest rate. GB_t is the Chinese government bonds yield, used as a proxy for risk measurement. Int_p and Int_s represent purchase and sale interventions, respectively. Table A in the Appendix reports the results from estimating the GARCH (1, 1) model. Given that the major objective of the PBOC is to stabilize the foreign exchange market, we expect that conditional volatility has a positive relation with intervention.

Lag of Intervention

Intervention is a sequential action. The central bank may intervene on many different days and its effects may last into next periods. In addition, the lag of intervention could reflect the political costs (Ito and Yabu, 2007). We use a lagged intervention variable to study its dynamic effects on triggering the subsequent intervention action.

4.4.3 Domestic Market Determinants

Conditions of the National Economy

The national economy has a mutual relation with the exchange rate level. The Chinese government publishes the target GDP growth rate every year. In the process

of reaching the growth target, the exchange rate is often used as a policy tool to influence external trade. To this end, government intervention plays a pivotal role in bringing the exchange rate to the level desirable for trade promotion. In this study, state of the national economy is proxied by the national stock price index.

Conditional Volatility Dummy Variable

In order to study different influences of the exchange rate volatility in the yuan appreciation or depreciation episodes, we introduce two dummy variables: one is for yuan appreciation, and takes the value of one when the yuan is appreciating and zero otherwise; the other is for yuan depreciation and takes the value of one when the yuan is depreciating and zero otherwise. We also use a third dummy variable, which takes the value of one when the conditional volatility is greater than the average level of volatility and zero otherwise, to test the impact of size of volatility on China's intervention decision. These dummy variables allow us to test whether high levels of volatility could lead to intervention.

4.4.3 Foreign Exchange Market Determinants

Interest Differentials

Interest differentials can be a proxy to indicate the possible degree of exchange rate overshooting (Kim and Sheen, 2002). In this research, the interest differential is calculated as the difference between the overnight rate in China's Shanghai

interbank market (the Shibor rate) and the US Federal Funds rate. If the interest rate differential increases (decreases), the RMB exchange rate would fluctuate upwards (downwards). The greater the exchange rate fluctuation, the higher is the possibility that the PBOC would step in to intervene.

Deviations from the Central Parity

China has published the central parity rate on every business day since 22 July, 2005. The parity acts as the benchmark of rate movements to anchor the RMB exchange rate system. If the spot RMB exchange rate exceeds or is below the central parity by too great a margin, the PBOC would apply intervention to stabilize the erratic exchange rate movements. As such, deviations of the spot RMB exchange rate from the central parity can be counted as an indicator of the possible advent of official intervention.

Inventory Imperatives

Inventory consideration of foreign reserves could be a factor that leads to intervention. In order to ensure the maintenance of the desired level of international reserves, central banks use intervention to adjust the reserve stocks. We use the ratio of foreign reserves to imports as an indicator of inventory needs. Given the daily frequency of all other variables, following Kim and Sheen (2002) the monthly reserves and imports data are converted to daily frequency through the spline function.

Foreign Direct Investment Flows

Foreign direct investment (FDI) is a major channel through which international capital moves in and out of China. It is also an extremely important driver behind China's economic growth. Therefore, this variable has become a focus of policy attention in China, and changes in it may trigger government intervention in the foreign exchange market. In order to test whether FDI flows exert an effect on intervention, we add the FDI variable into the models. As with the inventory needs, we convert monthly FDI data to daily data.

4.4.4 Data Statistics

Table 4.2 shows the summary statistics and stationarity tests for the variables. The results indicate that while deviations from previous 21-day and previous 5-day exchange rates, conditional volatility, deviations from the central parity, and FDI are stationary processes, other variables such as the reserves ratio, stock index, interest rate differentials and USD/CNY exchange rate are all non-stationary. However, these series may be stationary if taking into account the regime breaks during the sample period (broken-trend stationarity).

Table 4.2 Data Summary Statistics

	Dev21	Dev5	Stock index	Interest rate differentials	Conditional Volatility	Central Parity	Reserves ratio	FDI	USD/CNY exchange rate
Observations	2087	2087	2087	2087	2087	2087	2087	2087	2087
Mean	-0.0112	-0.0031	55.8076	0.4303	-14.2758	-0.0037	20.087	9.8624	6.9879
Median	-0.0069	-0.0012	58.28	1.07	-13.9956	-0.0004	20.4718	5.7414	6.8287
Maximum	0.0739	0.0556	104.18	13.69	-11.3667	0.06957	37.58	110.3277	8.109
Minimum	-0.1588	-0.1664	26.07	-3.93	-17.0827	-0.0674	12.2317	-36.6187	6.1214
Standard deviation	0.0198	0.0105	14.1108	2.5421	1.2744	0.1961	4.4964	22.1494	0.6224
Skewness	-1.5311	-2.3939	-0.0355	-0.0712	-0.5907	-1.1594	0.5414	1.4572	0.5283
Kurtosis	9.6485	9.9252	3.2338	2.5415	2.5168	6.4435	3.7458	6.9504	1.941
Stationarity test	Stationary	Stationary	Mixed	Mixed	Stationary	Stationary	Mixed	Stationary	Mixed

4.5 Modelling China's Official Intervention

First, we follow Almekinders and Eiffinger's (1996) approach, in which the intervention reaction function is derived formally rather than in an ad hoc way. That is, an intervention reaction function is estimated by combining the exchange rate model with a loss function for the central bank. The process of exchange rate is as follows:

$$s_t = s_{t-1} + \rho \text{Int}_t + \omega Z_t + u_t \quad (4.5)$$

where Z_t is the past information set, and ω is a row vector of coefficients.

The central bank is assumed to have a loss function that should be minimized using interventions. The loss function is estimated to be:

$$\text{Min}_{I_t} E[\text{Loss}_t | \Omega_{t-1}] = E[(s_t - s_t^*)^2 | \Omega_{t-1}] \quad (4.6)$$

where Ω_{t-1} denotes the information available to the monetary authorities and market participants at the end of date $t - 1$. The specification means that the loss is defined by squared deviation of the actual exchange rate from the target rate at date t .

Minimizing the loss function (4.6) by choosing I_t subject to the constraint (4.5) leads to the following intervention reaction function:

$$Int_t^* = -\frac{1}{\rho}(s_{t-1} - s_t^* + \omega Z_t) \quad (4.7)$$

Then, we generate a binary choice dependent variable which represents the probability of two types of intervention. The reasons for using a bivariate probit model are two. First, the intervention data exhibit nonlinearity, and are clustered. Therefore, if using the OLS estimator, the results would be inconsistent. In addition, errors of the OLS regression in this case may not be normally distributed. Because our CB intervention data are constructed as 1, 0 and -1, which is like a dummy variable. These promote us to use the probit model. Second, under the bivariate probit model, one can test for the effects of purchase and sale interventions in a common framework. We use the bivariate probit model as in Heckman (1987) to test determinants of intervention:

$$Int_{p,t}^* = \beta_1 x_{1t} + u_{1t} \quad (4.8)$$

$$Int_{s,t}^* = \beta_2 x_{2t} + u_{2t} \quad (4.9)$$

where $Int_{p,t}^*$ and $Int_{s,t}^*$ are latent variables. The actual intervention can be written as follows:

$$\begin{cases} Int_{l,t} = 1 & \text{if } Int_{l,t}^* > 0 \\ Int_{l,t} = 0 & \text{if } Int_{l,t}^* \leq 0 \end{cases}; l = p, s \quad (4.10)$$

where p and s are the purchase and sale interventions, respectively, and:

$$Int_{l,t}^* = \beta_{l,t}x_t + \varepsilon_t, \text{ with}$$

$$\begin{aligned} \beta_{l,t}x_t = & \alpha_0 + \alpha_{1,1}MED_t + \alpha_{1,2}SED_t + \alpha_{1,3}CV_t + \alpha_{1,4}Int_{l,t-1} \\ & + \alpha_{1,5}(CV_t)(Dapp_t)(Dsize_t) + \alpha_{1,6}(CV_t)(Ddep_t)(Dsize_t) \\ & + \alpha_{1,7}SI_t + \alpha_{1,8}ID_t + \alpha_{1,9}CP_t + \alpha_{1,10}RR_t + \alpha_{1,11}FDI_t \end{aligned} \quad (4.11)$$

where $Int_{p,t}$ is a dummy variable that takes the value of one when the type of intervention is purchase and zero otherwise; $Int_{s,t}$ is a dummy variable that takes the value of one when the type of intervention is sale and zero otherwise. MED_t and SED_t are deviations of the current exchange rate from the target exchange rate in the medium term (moving average of RMB exchange rates in the previous 21 days) and short term (previous 5 days), respectively; CV_t indicates conditional volatility of the RMB exchange rate; $Dapp_t$ and $Ddep_t$ are dummy variables for yuan appreciation and depreciation, respectively; $Dsize_t$ is a dummy variable taking the value of one if the size of exchange rate volatility exceeds the average level, and zero otherwise; Int_{t-1} is the lag of the dependent variable. SI_t is the MSCI China stock index, which is a proxy for conditions of the national economy; ID_t represents interest differentials between the Shibor overnight rate and the US Federal Funds rate; CP_t denotes deviations of the current market exchange rate from the central parity; RR_t is the ratio of official holdings of foreign reserves to Chinese imports; FDI_t represents foreign direct investment flows.

The bivariate probit model is estimated by the maximum likelihood method. In addition, this model is adjusted with heteroscedasticity consistent covariance matrix (Huber/White). This approach can help us eliminate the effect of heteroscedasticity.

4.6 Empirical Results

4.6.1 Whole Sample Results

Table 4.3 reports the estimation results for the whole sample using the bivariate probit model. The estimation is focused on the determination of China's purchase and sale interventions. We divide these determinants into three sets: basic determinants, domestic market determinants and foreign exchange market determinants. The basic determinants model includes just the exchange rate deviations, conditional volatility and lag of intervention variables; the domestic market determinants model adds the volatility dummy variables and national economy index; the foreign exchange market determinants model is the integrated regression, including interest differentials, central parity deviations, inventory imperatives, and FDI flow variables.

Table 4.3 Bivariate Probit Model Results for Basic, Domestic Market, and Foreign Exchange Market Determinants

	Basic Determinants		Domestic Market Determinants		Foreign Exchange Market Determinants	
	Purchase	Sale	Purchase	Sale	Purchase	Sale
Constant (α_0)	-0.512*** (0.191)	-0.757*** (0.206)	-1.068*** (0.137)	-0.735*** (0.142)	0.040 (0.246)	-0.015 (0.253)
Medium deviation (MED_t)	90.041** (38.673)	-95.339** (39.829)	77.965** (39.142)	-127.267*** (40.226)	93.660** (42.173)	-79.687* (43.331)
Short deviation (SED_t)	-112.310 (74.500)	143.695* (79.436)	-113.566 (73.814)	135.368* (81.047)	-123.318 (75.204)	110.277 (82.258)
Volatility (CV_t)	0.155 (0.162)	0.152** (0.067)				
Lag ($Int_{1,t-1}$)	0.400*** (0.078)	0.449*** (0.089)	0.449*** (0.078)	0.450*** (0.090)	0.368*** (0.079)	0.391*** (0.090)
Volatility (CV_t)($Dapp_t$)($Dsize_t$)			0.105*** (0.357)	-0.169*** (0.0344)	0.153*** (0.038)	-0.172*** (0.036)
Volatility (CV_t)($Ddep_t$)($Dsize_t$)			-0.180*** (0.036)	0.083* (0.047)	-0.133*** (0.039)	0.079 (0.050)
Economy (SI_t)			0.001 (0.003)	-0.011*** (0.003)	0.007** (0.003)	-0.009*** (0.003)
Interest rate differentials (ID_t)					0.079*** (0.019)	0.031 (0.020)
Central parity deviations (CP_t)					0.156 (1.638)	-6.603*** (1.873)
Inventory imperatives (RR_t)					-0.069*** (0.012)	-0.043*** (0.012)
FDI flows (FDI_t)					-0.005*** (0.002)	-0.001 (0.002)
log-likelihood	-1713.253		-1680.471		-1641.209	
Observations	2086		2086		2086	

Notes: Figures in parentheses are Standard Errors. ***means the coefficient is significant at 99% level; **means significant at 95%; *means the 90% significance level.

Results from Basic Determinants Model

For the basic determinants model, our analysis of the results begins by explaining the influence of exchange rate deviations. We find evidence that the medium-term deviations are positively and significantly related with purchase intervention, and are significantly negatively related with sale intervention, while coefficients on the medium-term deviations α_1 are positively and negatively significant for purchase and sale interventions respectively. This suggests that a current appreciation (depreciation) of the RMB exchange rate could induce a higher probability of purchase (sale) intervention by the PBOC, giving empirical evidence for the leaning-against-the-wind hypothesis. In addition, the coefficient on the short-term deviation α_2 is positively marginally significant only for the sale intervention at 10% level, implying that a short-term appreciation of the RMB exchange rate leads to a higher probability of sale intervention. Therefore, evidence for the short-term deviations proves that the PBOC applies leaning-with-the-wind interventions in short-term intervention decisions.

The coefficient on conditional volatility α_3 is positively significant, suggesting that the conditional volatility has a significant and positive influence on the sale intervention in the whole period. This indicates that a higher volatility of exchange rate changes is associated with a higher probability of sale intervention. Given that a major policy objective of the PBOC is to stabilize the RMB exchange rate, it is conceivable that a higher degree of exchange rate conditional volatility boosts the probability of the Chinese central bank increasing the supply of foreign exchange to the market, hence the increased sale intervention. However, similar to the results

from Kim and Sheen (2002), growing conditional volatility has no significant effect on triggering purchase intervention, presumably because withdrawal of liquidity from the foreign exchange market would only serve to intensify volatility of the exchange rate. As such, the signs for the variable of conditional volatility suggest that the PBOC does not worry about market turbulence when the yuan is perceived to be strong.

The lagged intervention shows a statistically significant positive impact for both purchase and sale interventions, since the coefficients on the lagged intervention α_4 are positive and significant for purchase and sale intervention at 1% level. This indicates that, if a purchase (sale) intervention happened on the previous day, the likelihood of another purchase (sale) intervention appearing in the following days is high.

Results from Domestic Market Determinants Model

The results for exchange rate deviations and lagged intervention variables in the domestic market determinants model are similar to the results from the basic determinants model. The positively and negatively significant coefficients on medium-term deviations α_1 for purchase and sale interventions show that appreciation (depreciation) of the RMB exchange rate leads to China's purchase (sale) intervention, supporting the leaning-against-the-wind hypothesis. Moreover, empirical evidence indicates that the PBOC uses lean-with-the-wind intervention in the short term, since the short-term deviations are shown to have marginally significant impacts for sale intervention and no significant impact for purchase

intervention. Furthermore, the coefficients on lagged intervention α_4 are positively and statistically significant for both purchase and sale interventions. This suggests that intervention is a sequential process; that is, the probability of intervention following previous day intervention is high.

Conditional volatility on days with larger than sample average conditional volatility has positively significant effects on purchase intervention when the yuan is appreciating, and for sale intervention when the yuan is depreciating. The coefficients on volatility dummy variables α_5 and α_6 are significantly positive and negative for the purchase intervention, while the signs of coefficients α_5 and α_6 for sale intervention are opposite to the signs for purchase intervention. Therefore, we can obtain evidence that a further rise in volatility associated with an appreciation (depreciation) induces the purchase (sale) of US dollars, which is conditioned by the PBOC's policy objective not to allow big swings of the RMB rate. Compared with the results of the volatility variable in the basic determinants model, we can obtain more insights from the volatility dummy variables: when the yuan appreciates, China's purchase intervention would be caused by larger than sample average conditional volatility, but not by normal magnitude of volatility.

As can be seen from Table 4.3, the result for the coefficient on national economic conditions α_7 shows that state of the national economy has only negative and significant effect on sale intervention probability over the whole sample period. When China's economy is performing badly, the USD/CNY exchange rate tends to depreciate. To promote growth through importing, sale intervention is used as a tool to combat exchange rate depreciation.

Results from Foreign Exchange Market Determinants Model

Results for the domestic market determinants in the foreign exchange market determinants model are similar to those in the domestic market model. Two exceptions are that in sale intervention estimations, the marginally significant effects of short-term deviations and the volatility associated with depreciation disappear. The reason is likely to be that the Chinese monetary authorities use the setting of the central parity as a substitute for sale intervention. Given that the PBOC aims to stabilize the exchange rate movements around the central parity rate, it could control the exchange rate volatility by maintaining the exchange rate level at the short-term target level (the daily central parity rate).

The other difference is that in purchase intervention estimations, the national economic condition variable has a significant influence. It is plausible that the national economy variable is associated with international reserves and FDI flows (Table 4.4). Polterovich and Popov (2002) and Lin (2011) prove that countries with growing foreign reserves exhibit higher rates of GDP growth. In addition, Alfaro et al. (2004) and Azman-Saini et al. (2010) obtain empirical evidence that FDI has a positive impact on growth. As such, the PBOC would take into account all these factors in purchase intervention decisions.

Table 4.4 Correlation between FDI, International Reserves and National Economy

	FDI	International reserves	National Economy
FDI	1		
International reserves	-0.208***	1	
National Economy	0.405***	0.227***	1

Notes: ***means the coefficient is significant at the 99% level; **means significant at 95%, and * means significant at the 90% level.

The positively significant coefficient on interest rate differential α_8 for purchase intervention indicates that when the spread between China's interest rate and the US interest rate becomes wider, the probability of the Chinese authorities engaging in purchase intervention is higher. This implies that when interbank liquidity becomes tighter, hence the interest rate differentials between China and the US become greater, the Chinese authorities tend to purchase the foreign currency to mitigate the pressure for the RMB to appreciate against foreign currencies.

The central parity deviations have only a negative effect on sale intervention estimations, meaning that when the spot RMB exchange rate is less than the central parity rate (depreciation), the likelihood of sale intervention is higher. In order to get more detail about the effects of central parity deviations, we add two dummy variables into exchange rate deviations: $Bsize_t$ and $Ssize_t$.⁹ As indicated in Table 4.5, the purchase intervention decision is influenced by consideration of the central parity deviations when they are greater than the average deviation level, and sale

⁹ $Bsize_t$ is a dummy variable that takes the value of one if the size of central parity deviations exceeds the average level, and zero otherwise; and $Ssize_t$ is a dummy variable that takes the value of unity if the size of central parity deviations is less than the average level, and zero otherwise.

intervention is associated with the central parity deviations being below the average level of deviations.

Table 4.5 Results for Effects of Central Parity Deviations

	Foreign exchange market model	
	Purchase	Sale
Constant (α_0)	-0.132 (0.252)	-0.088 (0.257)
Medium deviation (MED_t)	46.863 (42.301)	-83.321** (42.534)
Short deviation (SED_t)	-86.416 (75.393)	110.526 (81.988)
Lag ($Int_{1,t-1}$)	0.333*** (0.080)	0.373*** (0.091)
Volatility (CV_t)($Dapp_t$)($Dsize_t$)	0.169*** (0.038)	-0.177*** (0.036)
Volatility (CV_t)($Ddep_t$)($Dsize_t$)	-0.111*** (0.038)	0.070 (0.050)
Economy (SI_t)	0.008*** (0.003)	-0.010*** (0.003)
Interest rate differentials (ID_t)	0.063*** (0.020)	0.014 (0.201)
Central parity deviations (CP_t)($Bsize_t$)	15.695*** (3.326)	
Central parity deviations (CP_t)($Ssize_t$)		-10.730*** (2.188)
Inventory imperatives (RR_t)	-0.064*** (0.012)	-0.039*** (0.013)
FDI flows (FDI_t)	-0.004** (0.002)	-0.0002 (-0.002)
log-likelihood	-1627.005	
Observations	2086	

Notes: Figures in parentheses are Standard Errors. ***means the coefficient is significant at the 99% level; **means significant at 95% and * means significant at 90% level.

The inventory constraint has negative and statistically significant effects on both purchase and sale interventions. That is, the greater the size of international reserves, the lower the probability of intervention. An increase in the international reserves implies an increase in the country's macro-prudent position, hence relatively less need to worry about exchange rate movements.

FDI flows also have a negatively significant effect on purchase intervention. The reason may be the same as that for the inventory constraint. Increased FDI inflows strengthen China's balance of payments position and are generally healthy and beneficial. This would reduce the PBOC's impetus to intervene to 'get the exchange rate right'.

4.6.2 Results from the Financial Crisis Period

Table 4.6 presents the results from estimating the financial crisis period (15 July, 2008 to 23 June, 2010) with the bivariate probit model. The results provide evidence that during the global financial crisis, the main objective of the PBOC was to stabilize the Chinese foreign exchange market volatility. Because of the regime shift during this crisis period, the Chinese central parity rates were pegged to the US dollar. In order to keep the RMB exchange rate around the central parity rate, China's intervention operation was largely influenced by the exchange rate deviation factor. The coefficients on exchange rate deviations α_9 are positively and negatively significant for purchase and sale interventions, respectively, suggesting that if the spot exchange rate exceeds (or is below) the central parity, the probability of purchase (sale) intervention is higher. This also provides supportive evidence that the PBOC relies more on central parity deviations than on conditional volatility as a determining factor, and hence the volatility variables become insignificant in decisions on both purchase and sale intervention.

The national economy variable has a positive and significant effect on purchase intervention probability. The empirical evidence on this variable proves that during the financial crisis, the Chinese monetary authority was focused on maintaining GDP growth. To promote GDP growth, the PBOC applied purchase intervention to preserve and promote the volume of exports.

The short-term deviations and lagged intervention are positively related to sale intervention. This outcome indicates that the PBOC is significantly influenced by these two factors when making the sale intervention decision.

Table 4.6 Results for the Financial Crisis Period

	Foreign exchange market model	
	Purchase	Sale
Constant (α_0)	-2.725** (1.174)	0.132 (1.565)
Medium deviation (MED_t)	43.172 (168.157)	117.034 (183.445)
Short deviation (SED_t)	-40.666 (228.735)	511.776* (277.917)
Lag ($Int_{1,t-1}$)	0.330 (0.223)	0.548* (0.293)
Volatility (CV_t)($Dapp_t$)($Dsize_t$)	-0.064 (0.132)	-0.177 (0.146)
Volatility (CV_t)($Ddep_t$)($Dsize_t$)	-0.243* (0.130)	-0.031 (0.172)
Economy (SI_t)	0.025** (0.012)	-0.020 (0.014)
Interest rate differentials (ID_t)	0.168 (0.188)	-0.148 (0.242)
Central parity deviations (CP_t)	35.973*** (13.783)	-39.255** (16.791)
Inventory imperatives (RR_t)	-0.011 (0.030)	-0.025 (0.036)
FDI flows (FDI_t)	-0.004 (0.004)	0.003 (0.004)
log-likelihood	-252.993	
Observations	507	

Notes: Figures in parentheses are Standard Errors. ***means the coefficient is significant at the 99% level; **means significant at 95% and * means significant at 90% level.

4.7 Conclusions

This chapter has examined the forces that drive China's central bank intervention in the foreign exchange market from a binary variable approach. The empirical evidence unearthed by this chapter suggests that exchange rate deviations, conditional volatility, lagged intervention, national economic conditions, interest rate differentials, deviations from the central parity, inventory needs and foreign direct investment have significant influence on China's intervention decision. The PBOC conducts intervention in a leaning-against-the-wind fashion in the medium term, while leaning-with-the-wind intervention is used in the short term. Evidence also shows that China intervenes through the conduit of buying or selling foreign exchange to constrain exchange rate volatility, with a view to ensuring that there are no big swings in the RMB exchange rate. A related interesting finding is that deviations of the exchange rate from the central parity would prompt the PBOC to intervene, highlighting the central role of the parity in China's management of exchange rate policy. In addition, large central parity deviations could trigger purchase intervention, and the sale intervention decision is usually taken when deviations from the central parity are of moderate scale.

While on some occasions the central bank may decide to intervene in consideration of an array of factors, it may sometimes be prompted by one single factor. In making purchase intervention decisions, the PBOC may consider national economy conditions, inventory imperatives, and FDI flows. However, in sale intervention decisions, the main driving forces are exchange rate volatility and short-term deviations.

We also find that, in response to the global financial crisis, the PBOC gave prominent consideration to stabilization of the exchange rate, which sheds light on how China used intervention to deal with great economic and financial turmoil.

Chapter 5

China's Intervention in the Foreign Exchange Market: The Case of the Central Parity

5.1 Introduction

Among the countries whose monetary authorities apply daily intervention, that is, intervention on most trading days, researchers have identified Germany (Almekinders and Eijffinger, 1994 and 1996), Russia (Tullio and Natarov, 1999) and Pakistan (Shah et al., 2009). To that list can be added China, where official daily intervention in the foreign exchange market has been a distinctive feature of exchange rate policy. As in other emerging market economies, the primary motivation of China's daily intervention is to align the exchange rate to fundamentals, as suggested in the 1985 Plaza Accord (Baille and Osterberg, 1997), and to stabilize a disorderly foreign exchange market (Szakmary and Mathur, 1997; Disyatat and Galati, 2007; Pointines and Rajan, 2011). However, despite its critical importance, little is understood about the country's intervention operation, and hence it is difficult to gain a useful perspective on China's exchange rate policy and its global repercussions. This calls for research attention.

In the new managed float regime, the central parity rate (CPR) plays a key role. On every business day, this rate is published by the authorities before the market

opening. It then remains valid for the day and all market transactions are based upon it. As well as providing an anchor for the system, the CPR is a policy indicator. In the process of setting the parity rate, the central bank takes into account current and expected economic conditions. Through setting the CPR at different levels, the central bank may affect the benchmark for transactions in the marketplace, anchoring stability of the Chinese foreign exchange market and transmitting policy signals to market participants.

This chapter is motivated to examine China's intervention in the central parity rate (the daily price intervention) because of its primary importance in the nation's intervention nexus; such research will help to achieve a better understanding of China's exchange rate policy, which is increasingly exhibiting global influences. To this end, the first important dimension concerns the determinants of such intervention. The first challenge is to model a reaction function based on a non-linear relationship, because intervention in the CPR does not increase or decrease by approximately the same magnitude. Previous studies have shown that Tobit models are appropriate when the research interest lies in the magnitude of intervention rather than the probability (Humpage, 1999; Brandner and Grech, 2005). However, because thresholds vary depending on individual characteristics (Omori and Miyawaki, 2010; Nakayama et al., 2010), we combine the Tobit analysis with covariate dependent thresholds. The chapter begins by using the Bayes Tobit model as the reaction function.

The research described in this chapter contributes to a better understanding of the Chinese exchange rate policy in several ways. First, we structure a daily price intervention index by comparing the central parity rate to the daily fair value USD/CNY exchange rate estimated according to the IFV approach. Second, the finding of significant effect of three determinants underlying the process of China's setting of the CPR contributes to the debate on the true nature of the Chinese exchange rate regime. The determining factors are evaluation of the RMB (proxied by the market makers' offer rate), international currency movements (proxied by the Broad Dollar Index compiled by the US Federal Reserve), and macro conditions of the Chinese economy (proxied by the yield curve spread between short and long bond yields).

The results from the Bayes Tobit models show that, in general, these factors have significant effects on China's daily price intervention in the whole sample. Results for the whole sample suggest that China follows a leaning-against-the-wind policy, and conditions of domestic economy and foreign market can impact daily price intervention. Furthermore, coefficients on the determinants are found to be time-varying across different sub-samples, and between high and low intervention. The evidence indicates that China's daily price intervention is multi-faceted. With regard to high intervention, the policy objective during all the sub-sample time periods relates to market exchange rate condition. For low intervention, the policy objective ranges from restraining the domestic economy from overheating before the financial crisis, to a focus on market exchange rate conditions during and after the financial crisis.

The rest of this chapter is organized as follows. Section 5.2 presents a review of related literature. Section 5.3 describes measurement of China's daily price intervention and the data deployed in the study. Section 5.4 estimates the Tobit and the Bayes Tobit models. Section 5.5 reports the estimation results. Section 5.6 presents the main findings of the chapter.

5.2 Related Literature

The process of setting the central parity rate in China is quite similar to that of the London Gold Fix and the central parity rate in the European foreign exchange market. According to Harvey (2008), the Gold Fix is generally accepted as a true indication of conditions on the international market; for example, Aggarwal and Lucey (2007) argue that it provides a benchmark for gold bullion. The function of the London Gold Fix is to attain 'equilibrium between buyers and sellers' (Harvey, 2008); that is, it is determined by the gold market conditions. In theory, in order to ensure a stable economic environment, the central parity rate in the European foreign exchange market should be set close to the equilibrium exchange rate (Horvath and Komarek, 2006).

The first wave of literature on the intervention reaction function is limited to certain developed markets. For instance, in order to identify the determinants of the intervention behaviour of the Reserve Bank of Australia from 1983 to 1997, Kim and Sheen (2002) test five factors: exchange rate deviations, conditional volatility of the exchange rate changes, the overnight interest rate differentials between the US and Australia, profitability of foreign exchange intervention, and inventory

consideration of foreign currency reserves. Jun (2008) finds that the friction model does not outperform a linear model as reaction function for the Deutsche mark-US dollar market, because the friction model is found to have lower MAE but higher RMSE both in and out of sample. The most developed country studied with intervention reaction function is Japan, especially after the publication of intervention data by the Japanese monetary authorities (Ito, 2003 and 2005; Frenkel et al., 2004; Ito and Yabu, 2007; Beine et al., 2009).

Because of the nonlinearity in the intervention data, OLS estimates of central banks' intervention are inconsistent (Jun, 2008; Hall and Kim, 2009; Chen et al., 2012). In order to overcome this problem, researchers apply the Tobit models in their intervention studies. Using daily exchange and intervention data from 1993 to 1998, Brandner and Grech (2005) estimate a Tobit model to analyse central bank interventions in ERM I members, Belgium, Denmark, France, Ireland, Portugal and Spain. Their results show that the exchange rate position in the band (deviation from DEM central parity) significantly leads to intervention operation. However, there is less evidence that a change in market conditions (the volatility variables) induces foreign exchange intervention. Herrera and Ozbay (2005) test the determinants of foreign exchange intervention in Turkey from 1993 to 2003 using a Tobit model and Powell's CLAD estimator. Results show that although the degree of persistence in interventions decreased after the change from managed float to free float, lags of intervention variables in both purchase and sale equations are statistically significant in both periods. Using Japanese intervention data from 1991 to 2004, Chen et al. (2012) find empirical evidence to prove that the Tobit-GARCH model is a better central bank intervention function than other conventional models. Through

applying a Tobit-GARCH reaction function, Echavarria et al. (2013) prove that the transparent and pre-announced daily interventions applied by Colombia in 2008-2012 have much larger effects than secret interventions applied in 2004-2007.

Among recent studies on intervention in emerging market economies, Loiseau-Aslanidi (2011) considers the Georgian foreign exchange market by using squared changes in the exchange rate as a measurement of volatility. The study finds that volatility can trigger intervention. Jackman (2012) tests the Barbadian foreign exchange market and gets evidence that higher interest rate spreads may reduce sale intervention, but do not trigger purchase intervention. Similar research has been conducted for other emerging or developing economies such as Turkey (Akinci et al., 2006; Herrera and Ozbay, 2005), Argentina (Brause, 2008) and Pakistan (Mehdi et al., 2012). Research focusing directly on the Chinese official intervention has started to emerge only recently. The main contributors to this sparse literature are Chinese economists in domestic forums, with an overwhelming focus on the effects of official intervention (Lu, 1999; He, 2007; Xie et al., 2008; Liang and Mo, 2013; Wang, 2013).

5.3 Data Description

5.3.1 Measures of Central Parity Rate Intervention

Development of the Central Parity Rate

This chapter concentrates on the daily price, or CPR, intervention. Table 1 shows the process of the development of the central parity rate. According to a PBOC announcement, the managed float system started on 21 July, 2005 (PBOC, 2005). From that date the RMB exchange rate was not simply pegged to the US dollar, and so could better reflect market conditions. On 29 December, 2005, the State Administration of Foreign Exchange (SAFE) authorized 13 banks to launch the market maker service (SAFE, 2005). Today there are 34 market makers (SAFE, 2014). Before 4 January, 2006, the central parity rate was set by the closing price exchange rate of the previous day. However, with the introduction of the over-the-counter (OTC) transaction, the PBOC changed the formation of the CPR (PBOC, 2006). In the new system, the China Foreign Exchange Trade System (CFETS) asks the exchange rate prices from the market makers before the opening time of the foreign exchange market, and these prices are used as the calculation sample of the central parity rate. Then, after deleting the highest and the lowest price, the weighted average of these exchange rate prices is calculated. The weighted average price is the central parity rate. The weights are based on the trading volume of market makers and the conditions of exchange rate prices. From Table 5.1, we can see that the PBOC has gradually increased the width of the exchange rate band, making changes on 21 May, 2007 (PBOC, 2007), 16 April, 2012 (PBOC, 2012), and 17 March, 2014 (PBOC, 2014). This serves the PBOC's purpose, which is to increase the elasticity of the RMB exchange rate.

Table 5.1 Developments of China's Central Parity Rate Policy

Date	Event
21/07/2005	Launch of the managed float system with reference to a basket of currencies
29/12/2005	13 banks become the market makers
04/01/2006	Central parity rate combines OTC transactions and negotiation
21/05/2007	Exchange rate band changes from 0.3% to 0.5%
16/04/2012	Exchange rate band changes from 0.5% to 1%
17/03/2014	Exchange rate band changes from 1% to 2%

The daily central parity is published by the CFETS at 9:15; this is fifteen minutes before the start of the foreign exchange opening hours, which run from 9:30 to 15:30 Beijing time. The price-setting process for the central parity considers three functions (CFETS, 2013): the prices of central parity of all foreign exchange market makers asked by CFETS before the opening time; the changes in foreign exchange market conditions; and China's macro economy condition. As proxies for these three functions we use USD/CNY exchange rate prices from foreign exchange market makers, broad currency index, and the yield curve spread, respectively. Therefore, this research tests whether or not USD/CNY exchange rate prices, broad currency index and the yield curve spread are determinant factors of daily price intervention.

Some Chinese studies argue that the PBOC controls the RMB exchange rate through the central parity rate. For example, Zhao et al. (2012) indicate that if the PBOC never loses control of the central parity rate, then the RMB exchange rate must follow the will of the PBOC. Similarly, Zhao et al. (2013) and Shen (2013) argue that the RMB exchange rate is controlled by the PBOC, as the PBOC decides the central parity rate. News reports might provide proof that the central parity rate can

indeed influence RMB exchange rate movement. For example, according to reports in *The Wall Street Journal*, the RMB exchange rate followed the guidance of the central parity rate on 12/09/2014, 16/09/2014, and 08/10/2014. However, the literature in English includes very little on daily price intervention. This chapter tries to fill this critical void.

Measuring China's Daily Price Intervention

In this chapter we construct a daily price intervention ratio by comparing the CPR with the fair value USD/CNY exchange rate estimated by the indirect fair value (IFV) approach. From the fair value exchange rate, we can find out at what level the exchange rate should be.

Over the years, a number of models of currency fair value have been developed. Financial markets have developed formulas and models to derive fair values for futures, bonds, options, swaps and other securities (Aries et al., 2006). Empirical estimations make extensive use of purchasing power parity (PPP) (Officer, 1976), Penn effect (Summers and Heston, 1991), fundamental equilibrium exchange rate (FEER) (Williamson, 1983 and 1994), behavioural equilibrium exchange rate (BEER) (Clark and MacDonald, 1999) and indirect fair value (IFV) (Cenedese and Stolper, 2012) to measure exchange rate misalignment. In comparison with PPP, Penn effect, FEER and BEER, the IFV has some advantages: First, only IFV can focus on daily financial and macro data, while the other models have to use quarterly or yearly data (Zhang, 2012). Second, the fair value does not require restrictive

assumptions on financial market equilibrium to be operational (Clarida, 2013). Third, the IFV model benefits from ease of operability. Like the BEER model, IFV is estimated using co-integration techniques. To our knowledge, this IFV approach has not previously been formalized in the academic literature.

The IFV approach is based on the assumption that misaligned exchange rates are caused by speculative activity (Lyons, 2001). Risk reversals and international money market (IMM) positioning are two measures of speculative positioning often employed in this approach (Mogford and Pain, 2006). The first measure is the implied volatility differentials between comparable out-of-the-money call and put options. Compared with the demand for puts, demand for call options will greatly increase, leading to a rise in the price of call options. The second measure is dependent on the weekly Commitments of Traders (COT) report, which includes information about the positioning size of so-called non-commercial traders on the IMM futures exchange, part of the Chicago Mercantile Exchange (CME).¹⁰ Speculative positioning measures tend to be stationary and highly correlated with spot exchange rate (Campa et al., 1998; Mogford and Pain, 2006). In this research, because we use daily data, risk reversals are used to measure speculative positioning.

The following equation can express the relation between the exchange rate level and the speculative positioning:

$$e_t = \beta'Z_t + \theta'S_t + \varepsilon_t \tag{5.1}$$

¹⁰ For details on the COT reports, see: www.cftc.gov/marketreports/commitmentsoftraders/index.htm.

where e_t is the spot exchange rate observed in the FX market, Z_t is a vector of broadly defined fundamentals, S_t is speculative activity variables, ε_t is a residual error, and β and θ are vectors of coefficients.

From equation (5.1), it is possible to use the parameter estimates to calculate fair value in the following equation:

$$\bar{e}_t = \hat{\beta}' Z_t + \hat{\theta}' \bar{S} \quad (5.2)$$

with the overbar denoting the value of S , that is neutral speculative positioning. In most cases the choice of neutral speculative positioning is the sample mean.

If the CPR is contrary to the prediction of the market, and is 1% (Table 5.2 shows 0.3% during the period 22 July, 2005 to 21 May, 2007; 0.5% before 16 April, 2012), that is, 100% of the horizontal band, above/below the benchmark, it is marked as daily price intervention. The ratio of daily price intervention is estimated as follows:

$$I_t = \frac{CPR_t}{FV_t} \quad (5.3)$$

Table 5.2 Composition of Daily Price Intervention Index

Date	Percentage of horizontal band
22/07/2005—21/05/2007	0.3%
22/05/2007—15/04/2012	0.5%
16/04/2012—22/07/2013	1%

where I_t is the daily price intervention index, CPR_t is the present central parity rate, and FV_{t-1} is the fair value RMB exchange rate estimated by the IFV approach at day t . High intervention (depreciates the Chinese yuan) means the CPR is 100% higher than the benchmark, but if the daily price intervention ratio is 100% lower than the benchmark, it is termed low intervention (appreciates the Chinese yuan); otherwise there is no intervention. This means high intervention is larger than 1, and low intervention is smaller than 1.

For example, on 30/04/2009, the fair value exchange rate was 6.98, but the CPR was 6.83; this is interpreted as an appreciation of the RMB with intervention by the PBOC. Therefore, this date is marked as low intervention. On 03/02/2011, the markets considered the RMB fair value exchange rate should be 6.51, but the PBOC set the CPR at 6.59, indicating a depreciation of the RMB. Accordingly, this date is marked as high intervention.

5.3.2 Data Description and Statistics

The Dataset

The dataset analysed in this study contains daily intervention over an 8-year period starting on 22 July, 2005 and ending on 22 July, 2013, which represents a total of 2087 trading days excluding official holidays. To further understand the determinants of China's intervention, we additionally divide the whole sample into two sub-samples: 15 July, 2008 to 23 June, 2010, and the rest of the time, which is classified as the normal period. From Figure 5.1, it can be seen that the movements of the RMB exchange rate were flat during the period from 15 July, 2008 to 23 June, 2010, when, in response to the global financial crisis, China re-pegged its currency. We also use the $\sup_{\gamma}(F(\gamma))$ test (Andrews, 1993) to confirm that the structural break dates are 15 July, 2008 and 23 June, 2010. Based on Andrews (1993), the variable contained in the $\sup_{\gamma}(F(\gamma))$ test should not contain unit root. Table 5.3 shows that there is no unit root in RMB exchange rate based on the ADF and PP tests. The F-statistic at each break candidate (γ) can be obtained by the standard Chow test. From Figure 5.2 we find that the largest (4.86) F-statistic is in July 2008. While the second largest (3.63) F-statistic is in September 2010, we still choose June 2010 (2.73), because it was in that month that the PBOC announced the change of China's exchange rate regime from a peg to a managed float. We reject the null hypothesis, which is that there is no break, at 5% significance. Therefore, 15 July, 2008 and 23 June, 2010 are the structural break dates.

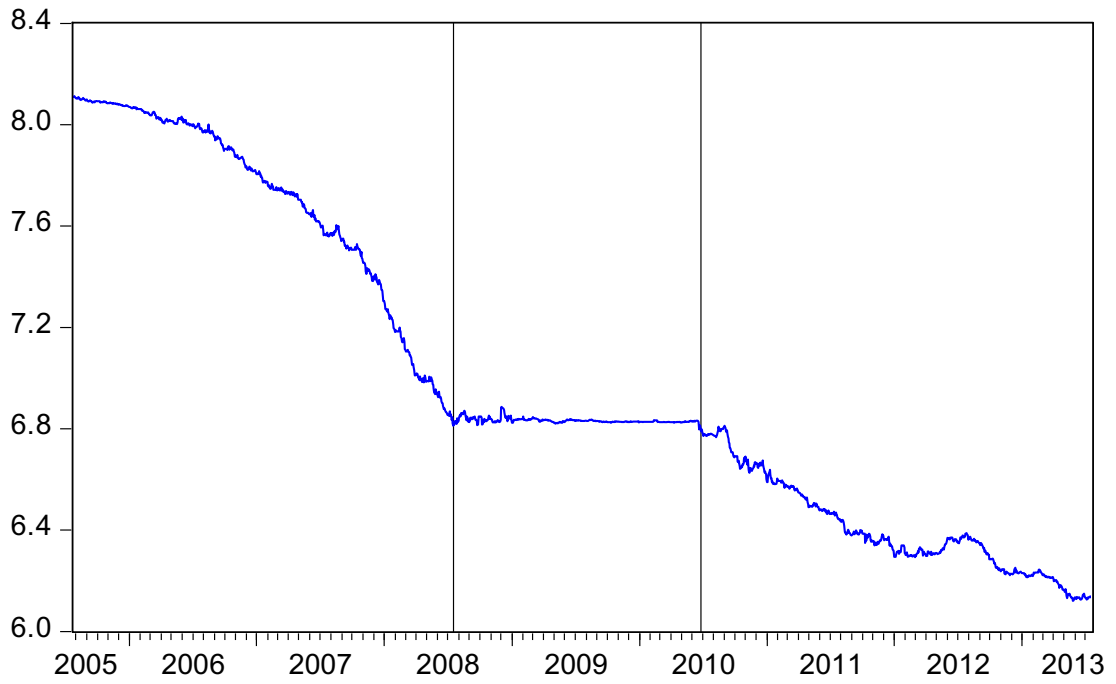


Figure 5.1 Movements of USD/CNY Exchange Rate

Table 5.3 ADF and PP Tests

Methods	t-Statistic
ADF	-3.423***
PP	-4.574***

Notes: *** significant at 1%, ** at 5%, * at 10% level; the null hypotheses for ADF and PP tests is that the variable follows a unit root process.

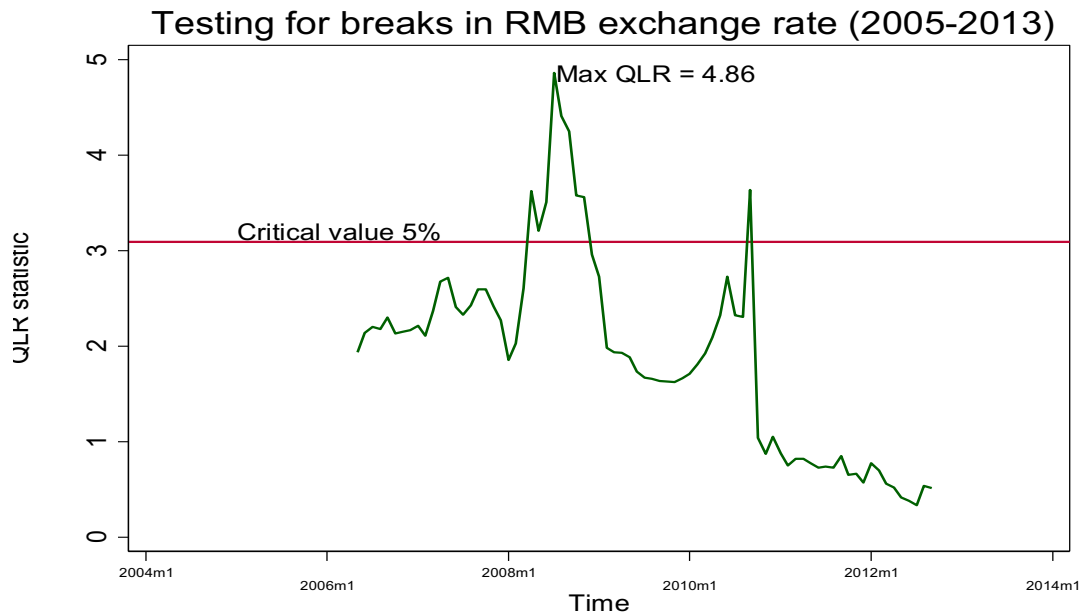


Figure 5.2 Regime Breaks in the RMB Exchange Rate (2005-2013)

Determining Factors

USD/CNY exchange rate prices. Similar to the London Gold Fix and European Currency Unit (ECU) concertation procedure, the RMB exchange rate central parity process involves USD/CNY exchange rate prices from foreign exchange market makers. Because the price of central parity provided by different makers is confidential, the makers' RMB exchange rate price is the best proxy for central parity price. Data on exchange rate prices are available for only six banks, and we cannot know the weights. In addition, we use the USD/CNY exchange rate in the US market to be the proxy for foreign banks' offers. The offers from foreign banks are less subject to control by the Chinese government and should follow the exchange rate in the US foreign exchange market. Moreover, although we do not know the weights, we know that the Bank of China occupies the greatest weight, as

the majority of foreign reserves are in the Bank of China. Therefore, this research first uses the average mean of the five banks' exchange rate prices and exchange rate in the US market, and then sums the exchange rate price from the Bank of China to be the price of central parity from foreign exchange market makers. The equation for USD/CNY exchange rate prices is as follows:

$$ERO = 60\%EROBC + 40\%EROM$$

$$MERO = ER - ERO \tag{5.4}$$

where ERO is the USD/CNY exchange rate prices, EROBC is the exchange rate price from the Bank of China, and EROM is the average mean of the five banks' exchange rate prices and exchange rate in the US market. In addition, MERO is the exchange rate prices deviation, equal to RMB exchange rate minus exchange rate prices.

Broad currency index. Unlike the London Gold Fix and the ECU concertation procedure, China's central parity also considers the changes in foreign exchange market conditions. We use broad currency index as the proxy for foreign exchange market condition. The broad currency index is a weighted average of the foreign exchange values of the US dollar against the currencies of a large group of major US trading partners, including China. It is an appropriate measure for the foreign exchange market condition, as we can use it to get the situations of the basket

currencies relevant to the RMB exchange rate movement.¹¹ The change of broad currency index is estimated as follows:

$$BCI_t = Index_t - Index_{t-1} \quad (5.5)$$

where BCI_t is the change of broad currency index, which is calculated by broad currency index on day t minus index on day t-1. Poor foreign exchange market condition would trigger daily price intervention by the PBOC. Therefore, we assume that the relation between the daily price intervention and the change of broad currency index should be negative.

The yield curve spread. The PBOC also needs to consider the condition of China's macro economy. The yield curve spread is a proxy for China's macroeconomic condition. Based on studies by Harvey (1988), Estrella and Hardouvelis (1991), and Rudebusch and Williams (2009), it can play a useful role in macroeconomic prediction. The yield curve spread used in this research is the 10-year government bond yield minus the 12-month government bond yield, gained through the following equation:

$$YC_t = 10YGB_t - 1YGB_t \quad (5.6)$$

¹¹ On 28th January 2011, PBOC Governor Zhou Xiaochuan stated that the RMB exchange rate refers to a basket of almost 20 currencies (PBOC, 2011).

where YC_t is the yield curve spread, $10YGB_t$ is the 10-year government bond yield, and $1YGB_t$ is the 12-month government bond yield. The relation between the yield curve and the economy should be positive (Estrella and Mishkin, 1998). From Figure 5.3, we can see that the yield curve has co-movement with the GDP growth.

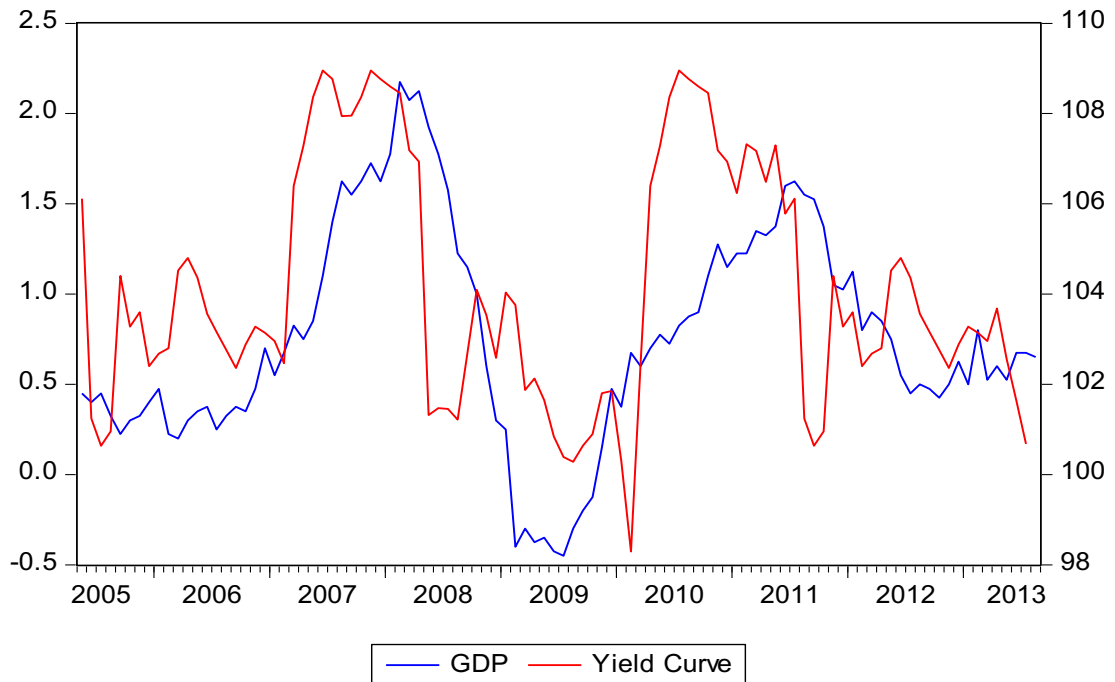


Figure 5.3 China's GDP and Yield Curve

Data Statistics

Table 5.4 presents the summary statistics and the correlation matrix for the variables. The low kurtosis¹² of high and low intervention shows that these data might not follow the normal distribution. The Tobit model with covariate dependent thresholds is to account for possible effects of outliers. From the correlation matrix, we can see

¹² Kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution. That is, datasets with high kurtosis tend to have a distinct peak near the mean (von Hippel, 2005).

that the bank RMB exchange rate and the broad currency index have significant relation with daily price intervention. However, the interaction among these variables may be more complex than a simple correlation can capture. It will therefore be interesting and informative to further investigate the extent to which these key variables interact in subsequent sections. Figure 5.4 presents the time series of daily intervention index.

The index of CPR intervention is a new measure that this thesis builds to get the CPR intervention data. This also contributes to the literature in a critical way. Based on the process of China's setting of the central parity rate, we set up three determinants to investigate China's intervention decision. Identification of these determinants is novel in that these factors are China specific and are not reported in the literature. Late empirical examination further validates the employment of these determining factors. For the limitations, because of the lack of official intervention information for comparison we cannot gauge the precision of these intervention data. In addition, these three determinants are of monthly instead of daily frequency, which means we need to further develop the proxies for the model of daily frequent data.

Table 5.4 Summary Statistics

	$EROM_t$	BCI_t	YC_t	I_t^h	I_t^l	I_t
Summary statistics						
<i>Obs.</i>	2087	2087	2087	1205	874	2079
<i>Mean</i>	0.003	2.011	1.138	0.441	0.310	1.001
<i>Std. dev.</i>	0.015	0.021	0.694	0.502	0.457	0.013
<i>Skewness</i>	22.60	0.285	0.154	0.261	0.795	-0.58
<i>Excess Kurtosis</i>	684.5	2.068	1.819	1.068	1.632	2.537
Correlation matrix						
$MERO_t$	1.000					
BCI_t	0.020	1.000				
YC_t	-0.009	0.675*	1.000			
I_t^h	-0.07*	-0.23*	-0.14*	1.000		
I_t^l	0.092*	0.236*	0.104*	-0.60*	1.000	
I_t	-0.08*	-0.26*	-0.12*	0.750*	-0.85*	1.000

Notes: The significance levels are displayed as * for 1%. $MERO_t$ is the bank RMB exchange rate prices, BCI_t is the broad currency index, YC_t is the yield curve spread, I_t^h and I_t^l are the high and low interventions, and I_t is the daily price intervention.

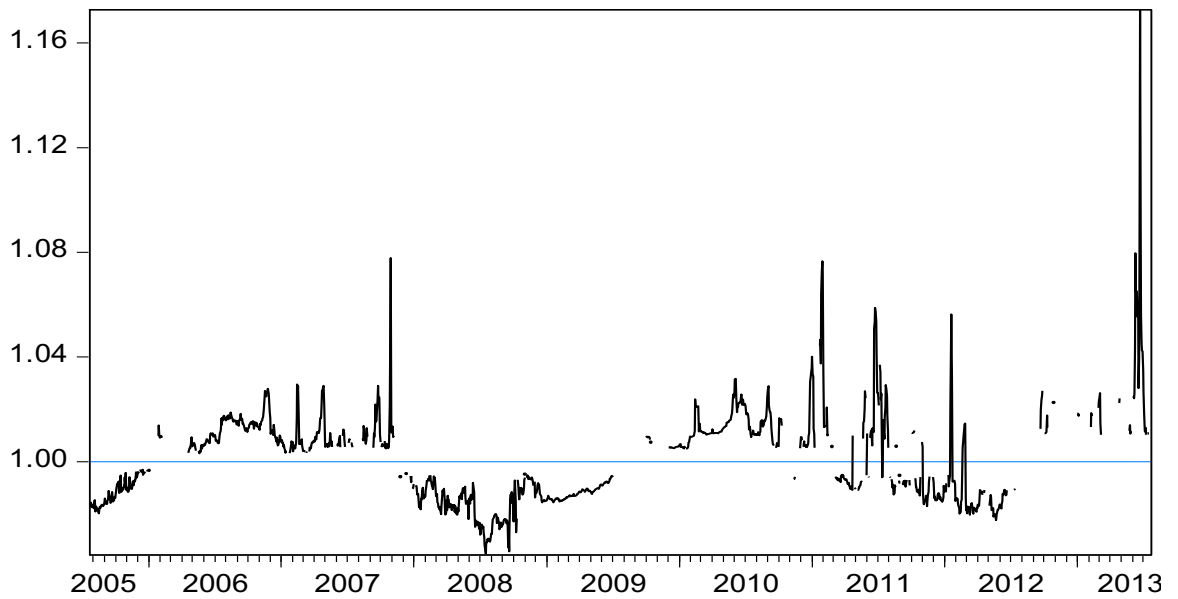


Figure 5.4 Daily CPR Intervention Index in Chinese Foreign Exchange Market during 2005-2013

Notes: High intervention is larger than 1; low intervention is smaller than 1.

5.4 Modelling China's Intervention Reaction Function

5.4.1 Tobit Regression

This section describes a censored regression model, that is, the Tobit model. The majority of Tobit models can be divided into five common types, according to the likelihood function (Amemiya, 1984). Table 5.5 shows each type of model characterized by the likelihood function, where y_1 , y_2 and y_3 are all assumed to be distributed as $N(x_j\beta_j, \sigma_j^2)$, $j = 1,2,3$, and P is a probability or a density or a combination thereof.

Table 5.5 Types of Tobit Model Classified by the Likelihood Function

Type	1	$P(y_1 < 0) \cdot P(y_1)$
	2	$P(y_1 < 0) \cdot P(y_1 > 0, y_2)$
	3	$P(y_1 < 0) \cdot P(y_1, y_2)$
	4	$P(y_1 < 0, y_3) \cdot P(y_1, y_2)$
	5	$P(y_1 < 0, y_3) \cdot P(y_1 > 0, y_2)$

Source: Amemiya (1984).

In the Tobit model, the dependent variable is called censored when the response cannot take values below (left censored) or above (right censored) a certain threshold value. In a censored sample, some values of interventions will be zero, which implies that the response of the dependent variable to the explanatory variables is nonlinear in the regression of intervention function (Chen et al., 2012). Therefore, OLS estimates of the foreign exchange intervention function will be inconsistent; that is, the residuals of the reaction functions are related with the explanatory variables. Tobit models overcome the problem whereby the dependent variable takes some zero values (see, e.g., Alkeminders and Eijffinger, 1994; Humpage, 1999; Brandner and Grech, 2005).

In this study, we use the Tobit model estimated by Herrera and Ozbay (2005) to estimate the intervention reaction function in China. The high intervention reaction function is written as follows:

$$I_t^* = x_t' \alpha + \varepsilon_t, \quad \varepsilon_t \sim i.i.d N(0, \tau^2)$$

$$I_t^h = I_t^* \text{ if } I_t^* > 0,$$

$$I_t^h = 0 \text{ if } I_t^* \leq 0,$$

$$\text{where } x_t' \alpha = \alpha_0 + \alpha_1 MERO_t + \alpha_2 BCI_t + \alpha_3 YC_t \quad (5.7)$$

where I_t^* is the latent variable, I_t^h is the observed censored value of high intervention, x_t' is the vector of exogenous explanatory variables at time t , b is the vector of unknown coefficients, $MERO_t$ is the USD/CNY exchange rate prices deviation, BCI_t means the broad currency index, YC_t is the yield curve between the 10-year and the 12-month China government bond yields, and ε_t is assumed to be normally distributed with variance σ^2 .

Similar to the equations of high intervention, the low intervention reaction function is formularized as follows:

$$I_t^* = x_t' b + \varepsilon_t,$$

$$I_t^l = I_t^* \text{ if } I_t^* < 0,$$

$$I_t^l = 0 \text{ if } I_t^* \geq 0,$$

$$\text{where } x_t' \alpha = \alpha_0 + \alpha_1 MERO_t + \alpha_2 BCI_t + \alpha_3 YC_t \quad (5.8)$$

where I_t^l is the observed censored value of low intervention.

In Tobit analysis, named after its pioneer Tobin (1958), when estimating the parameters in model (5.8) maximum likelihood procedures are consistently applied.

The scaled Tobit log likelihood function, $l_t(b)$, is given by:

$$l_t(b) = I(y_t > 0) \log \left(\sigma^{-1} \phi \left(\frac{I_t - x_t' b}{\sigma} \right) \right) + I(y_t = 0) \log \left(\phi \left(\frac{-x_t' b}{\sigma} \right) \right) \quad (5.9)$$

De Jong and Herrera (2004) estimate that maximizing the log likelihood function (5.9) over the set of possible parameter values $b \in B$ produces consistent estimates, $\widehat{\beta}_T$, of the dynamic Tobit model. Because $\widehat{\beta}_T$ has an asymptotic standard normal distribution, we can obtain standard errors using the computed Hessian of the log likelihood, or the quasi maximum likelihood estimate of the variance.

5.4.2 Tobit Model with Covariate Dependent Thresholds

The Tobit model with covariate dependent thresholds is a development of the standard Tobit model. Although Tobit models can overcome the problem whereby the dependent variable takes a value of zero most of the time, the coefficients cannot be estimated when the deterministic thresholds can vary with individuals depending on their characteristics (Omori and Miyawaki, 2010; Nakayama, 2010). There are two reasons for justifying the use of the Bayes Tobit model. First, the CPR intervention data set has the exact number rather than probability, which is different from the CB intervention data. In this case, the Tobit model is more fitting. Second, because China's exchange rate system has changed several times during recent years,

the thresholds of the exchange rate in the estimation vary depending on characteristics of the new regime. Therefore, Tobit analysis with covariate dependent thresholds, which is a Bayes Tobit model, is used. In such a model with covariate dependent thresholds, the i th response variable y_i is observed if it is greater than or equal to a threshold $d_i = w_i' \delta$ where w_i' and δ are a $J \times 1$ covariate vector and a corresponding coefficient vector, respectively. The vector w_i' consists of the covariates that impact the decision whether to engage in daily price intervention. Using a Bayesian approach, we describe a Gibbs sampler algorithm to estimate parameters.

First, we describe a Gibbs sampler for a Tobit (standard Tobit type 1) model (Chib, 1995). The prior distributions of (α, τ^2) are assumed to be a conditionally multivariate normal distribution and an inverse gamma distribution, respectively:

$$\alpha | \tau^2 \sim N(\alpha_0, \tau^2 A_0), \quad \tau^2 \sim \text{lg}\left(\frac{n_0}{2}, \frac{S_0}{2}\right), \quad (5.10)$$

where α_0 is a $K \times 1$ known constant vector, A_0 is a $K \times K$ known constant matrix, and n_0, S_0 are known positive constants. To implement a Markov Chain Monte Carlo method, we use a data augmentation method by sampling an unobserved latent response variable y_i^* . Using y^* , model (5.7) reduces to an ordinary linear regression model, $y^* = X\alpha + \epsilon$, where $y^* = (y_1^*, y_2^*, \dots, y_n^*)'$, $X' = (x_1, x_2, \dots, x_n)$ and $\epsilon = (\epsilon_1, \epsilon_2, \dots, \epsilon_n)' \sim N(0, \tau^2 I_n)$. Given y^* , the conditional posterior distributions of (α, τ^2) are:

$$\alpha|\tau^2, y^* \sim N(a_1, \tau^2 A_1), \quad \tau^2 \sim \text{lg}\left(\frac{n_1}{2}, \frac{S_1}{2}\right), \quad (5.11)$$

where $A_1^{-1} = A_0^{-1} + X'X$, $a_1 = A_1(A_0^{-1}a_0 + X'y^*)$, $n_1 = n_0 + n$, and $S_1 = y^{*'}y^* + a_0'A_0^{-1}a_0 + S_0 - a_1'A_1^{-1}a_1$. Let $y_0 = (y_{0,1}, y_{0,2}, \dots, y_{0,m})'$ and $y_c^* = (y_{c,1}^*, y_{c,2}^*, \dots, y_{c,n-m}^*)'$ denote $m \times 1$ and $(n-m) \times 1$ vectors of observed (uncensored) and censored dependent variables, respectively. Then, we can sample from the posterior distribution using a Gibbs sampler:

- (1) Initialize α and τ^2 .
- (2) Sample $y_c^*|\alpha, \tau^2 \sim TN_{(-\infty, d)}(x_i'\alpha, \tau^2)$, $i = 1, 2, \dots, n-m$, for censored observations, where $TN_{(a,b)}(\mu, \sigma^2)$ denotes a normal distribution $N(\mu, \sigma^2)$ truncated on the interval (a, b) .
- (3) Sample $(\alpha, \tau^2)|y_c^*, y_0$
 - (a) Sample $\tau^2|y_c^*, y_0 \sim \text{lg}(n_1/2, S_1/2)$,
 - (b) Sample $\alpha|\tau^2, y_c^*, y_0 \sim N(a_1, \tau^2 A_1)$.
- (4) Go to 2.

Next, we extend the above sampler by adding another step, whereby we can derive the Gibbs sampler for the Tobit model with covariate dependent thresholds. In the standard Tobit model (5.7), the threshold d is assumed to be known and a constant. However, it is usually unknown and may vary with the individual characteristics. Thus we extend it to allow unknown but covariate dependent thresholds as follows:

$$y_t^* = x_t'b + \varepsilon_t$$

$$\begin{aligned}
y_t &= y_t^* = x_t' b + \varepsilon_t \text{ if } y_t^* \geq w_i' \delta, \\
y_t &= 0 \quad \text{if } y_t^* < w_i' \delta.
\end{aligned} \tag{5.12}$$

where (w_i, x_i) are $J \times 1$ and $K \times 1$ covariate vectors and (δ, α) are corresponding $J \times 1$ and $K \times 1$ regression coefficient vectors. The known constant threshold d in (5.7) and (5.8) is replaced by the unknown but covariate dependent threshold, $w_i' \delta$.

To conduct a Bayesian analysis of the proposed Tobit model (5.12), we assume that prior distributions of (α, τ^2) are given by (5.11). A prior distribution of δ is assumed to be $\delta | \tau^2 \sim N(d_0, \tau^2 D_0)$, since we often use independent variables for w_i 's similar to those for x_i 's, and the magnitude of the dispersion is expected to be similar. If there is little prior information with respect to δ , we take large values for the diagonal elements of D_0 , which will result in a fairly flat prior for δ .

$$\begin{aligned}
\alpha | \delta, \tau^2, y^* &\sim N(a_1, \tau^2 A_1), \quad \tau^2 | \delta, \alpha, y^* \sim \text{lg} \left(\frac{n_1}{2}, \frac{S_1}{2} \right), \\
\delta | \alpha, \tau^2, y^* &\sim TN_{R_0 \cap R_c}(d_0, \tau^2 D_0),
\end{aligned} \tag{5.13}$$

where $n_1 = n_0 + n + J$, $S_1 = y^{*'} y^* + a_0' A_0^{-1} a_0 - a_1' A_1^{-1} a_1 + S_0 + (\delta - d_0)' D_0^{-1} (\delta - d_0)$, $A_1^{-1} = A_0^{-1} + X' X$, $a_1 = A_1 (A_0^{-1} a_0 + X' y^*)$, $R_0 = \{\delta | w_i' \delta \leq y_i \text{ for uncensored } i\}$, $R_c = \{\delta | w_i' \delta \leq y_i \text{ for censored } i\}$. The Gibbs sampler is implemented in three blocks as follows:

- (1) Initialize δ, α and τ^2 where $\delta \in R_0$.
- (2) Sample $y_c^* | \alpha, \tau^2, \delta, y_0$. Generate $y_{c,i}^* | \delta, \alpha, \tau^2 \sim TN_{(-\infty, w_i' \delta)}(x_i' \alpha, \tau^2), i = 1, 2, \dots, n - m$, for censored observations.
- (3) Sample $(\alpha, \tau^2) | \delta, y_c^*, y_0$
 - (a) Sample $\tau^2 | \delta, y_c^*, y_0 \sim \text{lg}(n_1/2, S_1/2)$,
 - (b) Sample $\alpha | \tau^2, \delta, y_c^*, y_0 \sim N(a_1, \tau^2 A_1)$.
- (4) Sample $\delta | \alpha, \tau^2, y^* \sim TN_{R_0 \cap R_c}(d_0, \tau^2 D_0)$.
- (5) Go to 2.

Steps 2 and 3 are similar to those in the simple Tobit model. To sample from the conditional posterior distribution of δ in Step 4, we generate one component δ_j of $\delta = (\delta_1, \delta_2, \dots, \delta_j)'$ at a time, given other components $\delta_{-j} = (\delta_1, \dots, \delta_{j-1}, \delta_{j+1}, \dots, \delta_J)'$. Since δ should lie in the region $R_0 \cap R_c$, the δ_j is subject to the constant $L_j \leq \delta_j \leq U_j$ where $w_{i,-j} = (w_{i1}, \dots, w_{ij-1}, w_{ij+1}, \dots, w_{iJ})'$,

$$L_j = \max_i L_{ij}, \quad L_{ij} = \begin{cases} w_{ij}^{-1}(y_i - w_{i,-j}' \delta_{-j}) & \text{if } w_{ij} < 0 \text{ for uncensored } i, \\ w_{ij}^{-1}(y_i^* - w_{i,-j}' \delta_{-j}) & \text{if } w_{ij} > 0 \text{ for censored } i, \\ -\infty, & \text{otherwise,} \end{cases}$$

$$L_j = \min_i U_{ij}, \quad U_{ij} = \begin{cases} w_{ij}^{-1}(y_i - w_{i,-j}' \delta_{-j}) & \text{if } w_{ij} < 0 \text{ for uncensored } i, \\ w_{ij}^{-1}(y_i^* - w_{i,-j}' \delta_{-j}) & \text{if } w_{ij} > 0 \text{ for censored } i, \\ -\infty, & \text{otherwise,} \end{cases} \quad (5.14)$$

Let $d_{0,-j} = (d_{01}, \dots, d_{0,j-1}, d_{0,j+1}, \dots, d_{0J})'$ and let $D_{0,j,j}$, $D_{0,j,-j}$ and $D_{0,-j,-j}$ denote a prior variance of δ_j , for $j = 1, 2, \dots, J$, using the conditional truncated normal posterior distribution,

$$\begin{aligned}
\delta_j | \delta_{-j}, \alpha, \tau^2, y^* &\sim TN_{(L_j, U_j)}(m_j, s_j^2 \tau^2), \\
m_j &= d_{0j} + D_{0,j,-j} D_{0,-j,-j}^{-1} (\delta_{-j} - d_{0,-j}), \\
s_j^2 &= D_{0,j,j} - D_{0,j,-j} D_{0,-j,-j}^{-1} D'_{0,j,-j}.
\end{aligned} \tag{5.15}$$

Note that this reduces to $TN_{(L_j, U_j)}(d_{0j}, \tau^2 D_{0,j,j})$ for a diagonal D_0 .

We estimate a Tobit model with covariate dependent thresholds to test whether the three factors (USD/CNY exchange rate bank offers, broad currency index and the yield curve) could be the determinants of China's daily price intervention:

$$I_t^* = x_t' b + \varepsilon_t, I_t^h = I_t^* \text{ if } I_t^* > w_i' \delta, \text{ and } I_t^h = 0 \text{ if } I_t^* \leq w_i' \delta,$$

Or

$$I_t^* = x_t' b + \varepsilon_t, I_t^l = I_t^* \text{ if } I_t^* < w_i' \delta, \text{ and } I_t^l = 0 \text{ if } I_t^* \geq w_i' \delta,$$

where $x_t' b = b_0 + b_1 EROM_t + b_2 BCI_t + b_3 YC_t$

$$\varepsilon_t | \Omega_{t-1} \sim N(0, \sigma_t^2), \tag{5.16}$$

5.5 Empirical Results

5.5.1 The Fair Value RMB Exchange Rate

Following the IFV approach, we estimate the fair value for the RMB exchange rate.

We try to get the exchange rate of the Chinese yuan against the US dollar from 22

July, 2005 to 22 July, 2013. The Z_t is the difference between US and Chinese 2-year swap rates, as well as linear, quadratic and cubic time trends. We use 1-month 25-delta risk reversals as a measure of speculative positioning in the regression (5.1). Before cointegration analysis, it is necessary to test unit roots in the time series in order to avoid spurious regression (Wang et al., 2007). Table 5.6 shows the results of Augmented Dickey-Fuller test. We find evidence that risk reversals are stationary, while the exchange rate and interest rate differential show a unit root. The ADF tests for risk reversals reject the null hypothesis that there is a unit root at 1% significance level. In fact, Figure 5.5 shows that risk reversals behave as a stationary time series with a sample mean, which is very close, but not equal, to zero.

Table 5.6 Augmented Dickey-Fuller Tests for the IFV Model

ADF test	<i>ER</i>	<i>Z</i>	<i>S</i>
t-Statistic	-0.524	-2.540	-4.148***

Notes: *significant at 10% level; **significant at 5% level; ***significant at 1% level.

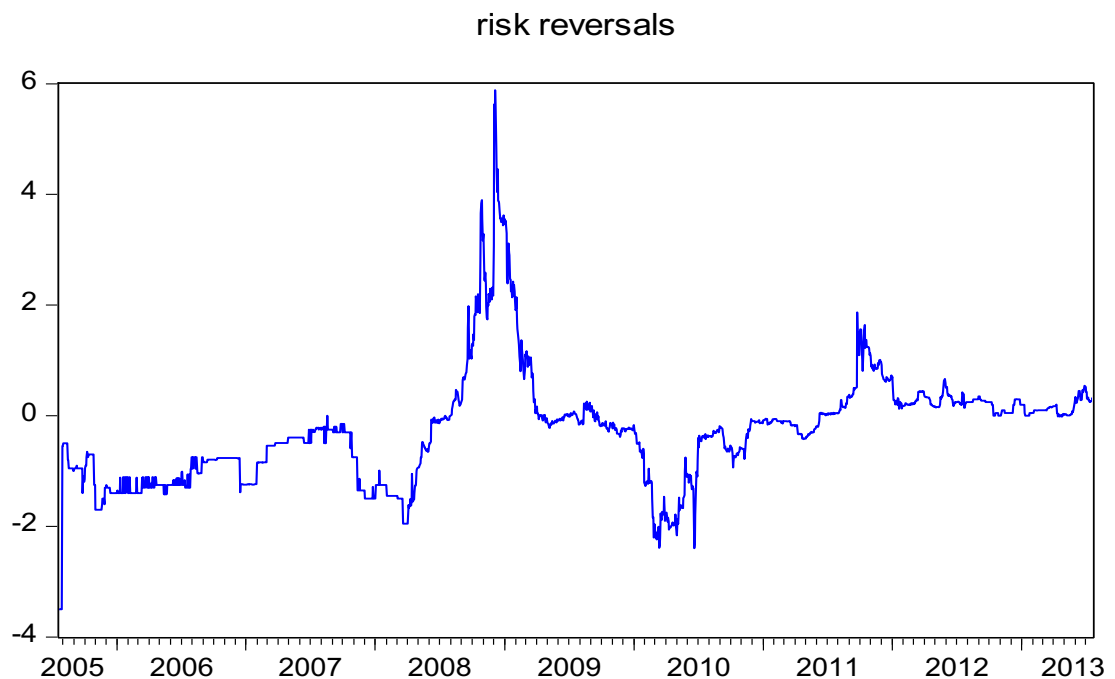


Figure 5.5 China's Risk Reversals

Figure 5.6 illustrates the results. The green line is the observed daily RMB exchange rate. The red line represents the fitted value of the regression using the raw data of all variables. Finally, the blue line displays the fair value exchange rate, which the exchange rate would have been without the impact of speculative activity. We use equation (5.2) to get the fair value, that is, as the fitted exchange rate but using the sample mean of the risk reversals instead of the observed values.

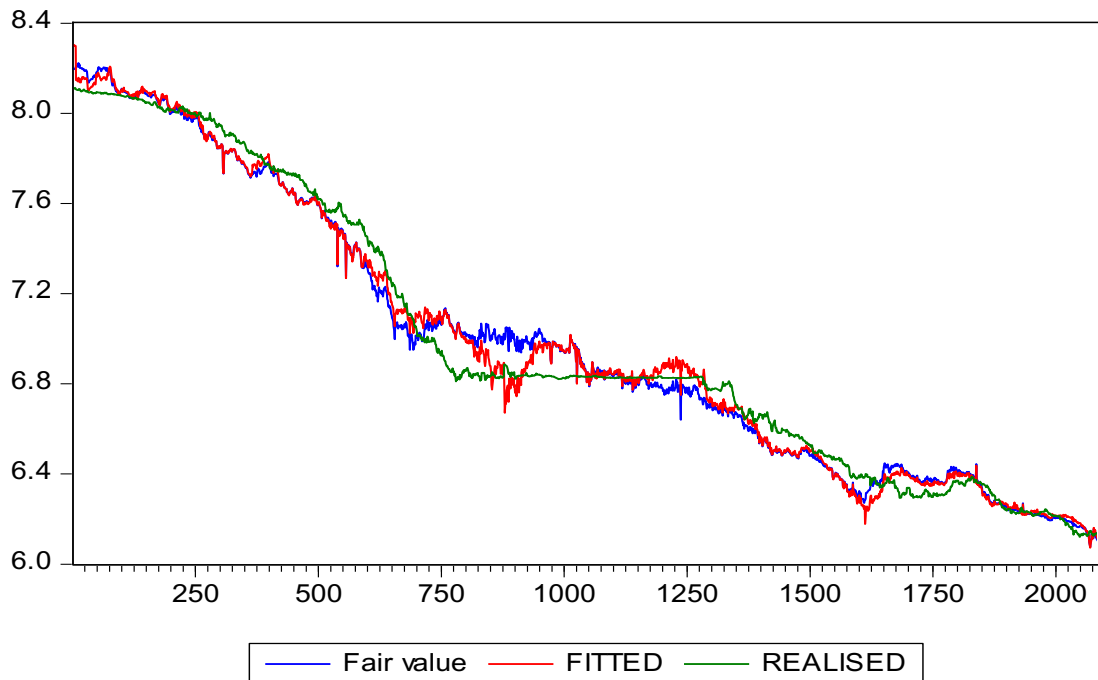


Figure 5.6 Movements of Renminbi's Fair, Fitted Value and Realized Value

5.5.2 Results for the Whole Sample Period

Table 5.7 presents the results for the whole sample period tested using the Tobit model with covariate dependent thresholds. In the models for the sub-sample periods,

the initial 1,000 variates are discarded as the burn-in period and the subsequent 30,000 values are recorded to conduct an inference. The number of daily price interventions in the whole sample is 1515, among which 43.6% of high interventions and 29% of low interventions are censored. Like daily intervention by the Bundesbank and Federal Reserve (Almekinders and Eijffinger, 1994 and 1996), China's daily price intervention occurred on more than half of all trading days.

The estimates do not reject the hypothesis that the PBOC followed a leaning-against-the-wind policy by reverting to its bank exchange rate prices. The 95% intervals for bank exchange rate price variables do not include zero, which means coefficients are significant at 5% level. The coefficient on bank exchange rate prices b_1 is negative (positive) and significant for high (low) intervention in the Tobit model with covariate dependent thresholds, which means that when the exchange rate prices appreciate (depreciate), the PBOC sets a higher (lower) central parity rate to reverse this appreciation (depreciation). This gives empirical evidence for the leaning-against-the-wind hypothesis.

The coefficients on broad currency index b_2 are negative and significant for high intervention, and are positive and significant for low intervention at 5% level in the Tobit model with covariate dependent thresholds, as the 95% intervals for broad currency index variables do not include zero. The broad currency index reflects the foreign exchange market conditions. Evidence shows that poor (good) foreign exchange market conditions would trigger daily price high (low) intervention by the PBOC. Through the use of daily price intervention, the PBOC makes efforts to improve foreign exchange market conditions.

Results in the Bayes Tobit model indicate that China's macro economy has negatively significant effect on low intervention, but has no effect on high intervention. The yield curve spread is the proxy for China's macro economy condition. Based on studies by Harvey (1988), Estrella and Hardouvelis (1991), and Rudebusch and Williams (2009), the relation between the yield curve and the economy should be positive. The coefficients on the yield curve b_3 are negatively significant for low intervention at 5% level. The low yield curve spread means that China's macro economy condition is bad. Then, the RMB exchange rate depreciates, reflecting the poor economic condition. Low intervention is used to offset the depreciation of the RMB exchange rate. Therefore, the low yield curve spread triggers intervention.

Referring to the magnitude of determinant coefficients in Table 5.8, the smallest numbers are those for the yield curve spread for both high (0.017) and low (-0.017) interventions. The difference between numbers for the yield curve spread variables and other variables shows that the yield curve spread represents the least important factor in the PBOC's intervention decision. The broad currency index is the most important factor.

Table 5.7 Tobit Model Results with Covariate Dependent Thresholds for the Whole Period

Full sample: 22/07/2005-22/07/2013						
	High intervention			Low intervention		
	Mean	Stdev	95% Interval	Mean	Stdev	95% Interval
Cons	26.92	3.298	(20.50,33.36)	-40.65	4.082	(-48.7,-32.72)

$MERO_t$	-12.85	3.636	(-20.12,-5.79)	6.242	1.781	(2.755,9.727)
BCI_t	-13.40	1.660	(-16.6,-10.16)	20.092	2.047	(16.12,24.14)
YC_t	0.017	0.048	(-0.078,0.11)	-0.225	0.060	(-0.34,-0.11)
τ^2	0.981	0.054	(0.882,1.091)	1.320	0.089	(1.16,1.51)

Notes: $MERO_t$ is the bank RMB exchange rate prices, BCI_t is the broad currency index, YC_t is the yield curve spread.

Table 5.8 Marginal Effects for the Whole Time Period

Full sample: 22/07/2005-22/07/2013		
	High intervention	Low intervention
$MERO_t$	-13.099*** (-3.534)	4.729*** (3.505)
BCI_t	-13.660*** (-8.072)	15.221*** (9.815)
YC_t	0.017 (0.354)	-0.170*** (-3.750)

Notes: The significance levels are displayed as *** for 1%, ** for 5%, and * for 10%. $MERO_t$ is the bank RMB exchange rate prices, BCI_t is the broad currency index, YC_t is the yield curve spread.

5.5.3 Results for Sub-samples: Before, During and After the Global Financial Crisis

The results for the three sub-samples from the Tobit model with covariate dependent thresholds are reported in Table 5.9. In the sub-sample models, as in the model for the whole sample, the initial 1,000 variates are discarded as the burn-in period and the subsequent 30,000 values are recorded to conduct an inference. The number of daily price interventions in sub-sample 1 is 606, among which 51.7% of high interventions and 26.3% of low interventions are censored. There are 367 observations for daily price intervention in sub-sample 2, of which 27.2% of high

interventions and 52.8% of low interventions are censored. In sub-sample 3, the number of interventions is 594, of which 68.4% of high interventions and 23.4% of low interventions are censored.

In sub-sample 1, 22 July, 2005 to 14 July, 2008, only the broad currency index factors have significant impacts on high and low intervention, as the 95% credible intervals do not include zero. The broad currency index variables are negative and significant for both high and low intervention. These results indicate that when making intervention decisions the PBOC considers the foreign exchange market conditions; that is, the PBOC tries to improve poor foreign exchange market conditions. For the yield curve spread, the coefficient b_3 is positive and significant for low intervention only. This suggests that the PBOC tries to cool down the overheating of economic growth by using low intervention.

In the financial crisis period, which is sub-sample 2, the aim of daily price intervention is to keep the RMB following the US dollar. The exchange rate regime during the financial crisis was a pegging regime, and hence the main objective of daily price intervention was to stabilize the exchange rate movements. Therefore, the coefficients on broad currency index b_2 are significant on both high and low intervention. The bank exchange rate prices variable influences high intervention only. The coefficient on the bank exchange rate prices b_1 is negative for high intervention. As with the result for sub-sample 1, the PBOC did use leaning-against-the-wind intervention. With regard to the yield curve spread, the coefficient on the yield curve spread b_3 is negative and significant for low intervention. This suggests

that in order to turn the economy from bad to good, the Chinese monetary authorities use low intervention, because low intervention can boost the import volume.

For sub-sample 3, all determinant factors, except yield curve spread, have significant impact on high and low intervention, as the 95% credible intervals do not include zero. The coefficient on exchange rate prices b_1 is negatively and positively significant for high and low intervention respectively. Similar to the result for the whole sample, this suggests that the PBOC uses leaning-against-the-wind intervention, and wants the RMB exchange rate to be impacted more by market conditions. Both high and low intervention decisions consider the foreign exchange market condition. The coefficients on the broad currency index b_2 are negatively significant for low intervention and positively significant for high intervention, both at 5% level. For the yield curve spread, the coefficients b_3 are positive and significant for high intervention, but not significant for low intervention. This means that the PBOC tries to boost economic growth through high intervention, because high intervention can boost the export volume.

According to the significance and magnitude of variables (Table 5.10) in these three sub-samples we find that the main objective of the daily price intervention is different in each case. For high intervention, the main objective across the sub-samples is to focus on the market exchange rate condition. For low intervention, the main objective before the financial crisis is to prevent the domestic economy overheating, while during and after the financial crisis the focus is upon market exchange rate condition.

Table 5.9 (1) Results of Tobit Model with Covariate Dependent Thresholds for Sub-sample 1 (22/07/2005-14/07/2008)

	High Intervention			Low Intervention		
	Mean	Stdev	95% Interval	Mean	Stdev	95% Interval
Cons	17.785	5.491	(7.115,28.661)	30.600	11.279	(9.272,53.335)
$MERO_t$	-2.893	5.096	(-12.963,7.005)	8.067	9.452	(-10.514,26.745)
BCI_t	-8.638	2.753	(-14.093,-3.293)	-16.006	5.683	(-27.456,-5.262)
YC_t	-0.087	0.070	(-0.224,0.052)	0.747	0.164	(0.439,1.088)
τ^2	0.763	0.064	(0.649,0.897)	1.685	0.209	(1.321,2.137)

Notes: $MERO_t$ is the bank RMB exchange rate prices, BCI_t is the broad currency index, YC_t is the yield curve spread.

Table 5.9 (2) Results Tobit Model with Covariate Dependent Thresholds for Sub-sample 2 (15/07/2008-22/06/2010)

	High Intervention			Low Intervention		
	Mean	Stdev	95% Interval	Mean	Stdev	95% Interval
Cons	53.625	13.808	(27.883,82.054)	-52.492	4.156	(-60.895,-44.528)
$MERO_t$	-40.742	21.409	(-84.215,-0.390)	9.110	6.023	(-2.616,21.037)
BCI_t	-27.208	6.915	(-41.483,-14.366)	26.440	2.070	(22.485,30.632)
YC_t	0.079	0.170	(-0.249,0.419)	-0.457	0.052	(-0.561,-0.356)
τ^2	2.264	0.414	(1.580,3.195)	0.469	0.047	(0.386,0.569)

Notes: $MERO_t$ is the bank RMB exchange rate prices, BCI_t is the broad currency index, YC_t is the yield curve spread.

Table 5.9 (3) Results of Tobit Model with Covariate Dependent Thresholds for Sub-sample 3 (23/06/2010-22/07/2013)

	High Intervention			Low Intervention		
	Mean	Stdev	95% Interval	Mean	Stdev	95% Interval
Cons	53.954	6.527	(41.343,67.018)	-69.18	14.984	(-99.684,-40.761)
$MERO_t$	-7.844	3.783	(-15.884,-1.405)	5.423	2.234	(1.075,9.817)
BCI_t	-27.193	3.281	(-33.767,-20.851)	34.15	7.504	(19.896,49.428)
YC_t	0.665	0.104	(0.465,0.873)	-0.0002	0.216	(-0.422,0.422)
τ^2	0.731	0.60	(0.625,0.858)	1.853	0.245	(1.432,2.393)

Notes: $MERO_t$ is the bank RMB exchange rate prices, BCI_t is the broad currency index, YC_t is the yield curve spread.

Table 5.10 Marginal Effects for Sub-samples

	Subsample 1 (22/07/2005-14/07/2008)		Subsample 2 (15/07/2008-22/06/2010)		Subsample 3 (23/06/2010-22/07/2013)	
	High intervention	Low intervention	High intervention	Low intervention	High intervention	Low intervention
$MERO_t$	-3.792 (-0.568)	4.788 (0.853)	-21.163** (-1.903)	19.424 (1.513)	-10.731** (-2.073)	2.927** (2.427)
BCI_t	-11.321*** (-3.138)	-9.499*** (-2.816)	-12.018*** (-3.935)	56.375*** (12.773)	-37.200*** (-8.288)	18.430*** (4.551)
YC_t	-0.114 (-1.243)	0.443*** (4.555)	0.035 (0.465)	-0.974*** (-8.788)	0.910*** (6.394)	-0.0001 (-0.0009)

Notes: The significance levels are displayed as *** for 1%, ** for 5%, and * for 10%. $MERO_t$ is the bank RMB exchange rate prices, BCI_t is the broad currency index, YC_t is the yield curve spread.

5.6 Conclusions

This chapter has employed a Bayes Tobit approach to evaluate the influences that drive China's central parity rate intervention. In order to estimate a proxy for daily price intervention data, we use the present central parity rate and daily fair value USD/CNY exchange rate estimated following the IFV approach.

In general, the results show that the bank RMB exchange rate prices, the broad currency index and the yield curve spread have significant effects on daily price intervention. The PBOC follows a leaning-against-the-wind policy by reverting to its bank exchange rate prices. In addition, bad (good) foreign exchange market and macro economy conditions can trigger high (low) intervention.

With regard to the time-varying determinants of daily price intervention, results show that determinant factors vary not only between different sub-samples, but also between the high and low interventions. We find evidence that across the different sub-samples the main objective for high intervention is to affect market exchange rate condition, while the main objective for low intervention ranges from restraining the domestic economy from overheating before the financial crisis, to a focus on market exchange rate condition during and after the crisis.

Chapter 6

Central Bank Intervention, Intervention Frequency and Threshold Effects: Evidence from the Chinese Yuan-US Dollar Foreign Exchange Market

6.1 Introduction

Major central banks, including the People's Bank of China (PBOC), apply central bank intervention as an important policy instrument to influence the foreign exchange market. Too much appreciation (depreciation) of exchange rate would negatively impact exporters (importers) and the confidence of the financial market. Therefore, the two main objectives of intervention are changing the level of the exchange rate in its intended direction, and calming excessive volatility, in terms of both the level and the speed of fluctuation (Utsunomiya, 2013).

There is an extensive body of economic literature that discusses whether foreign exchange interventions are effective. For instance, Kearns and Rigobon (2005) suggest that central bank interventions by the Reserve Bank of Australia and the Bank of Japan have economically and statistically significant effects to stabilize the exchange rate. However, several empirical studies find contrary results; that is, they find that central bank interventions move the exchange rate in the wrong direction (Baillie and Osterberg, 1997; Galati et al., 2005), or increase exchange rate volatility

(Dominguez, 1998; Baillie et al., 2000; Nagayasu, 2004; Beine et al. 2009). According to Neely's (2001) survey, among 22 central banks a majority relied on intervention to impact the foreign exchange market. Why do central banks continue to intervene if it is indeed ineffective? One possible explanation is the different exchange rate data used (Suardi, 2008), while another is that models used in the empirical studies do not correctly capture the exchange rate dynamics and the effects of intervention (Utsunomiya, 2013).

Recent research has shown that when analysing foreign exchange volatility, it is very important to consider asymmetric volatility in the foreign exchange markets (Brooks, 2001; Basci and Caner, 2005; Wang and Yang, 2009; Park, 2011). Based on empirical evidence of nonlinearities in the exchange rate time series, Brooks (2001) proves that a linear model of the exchange rate may produce invalid inferences when used to assess the effects of central bank intervention. Despite this disadvantage of linear models, there has been very little application of nonlinear models in the analysis of central bank intervention. There is still room for improvement of the nonlinear models, and therefore we consider them in this chapter.

The threshold autoregressive model is one of the nonlinear time series models capable of yielding asymmetric limit cycles. For example, Tong and Lim (1980) find that the threshold model can produce asymmetric and periodic behaviour exhibited in the annual Wolf's sunspot and Canadian lynx data. Because parameters of monetary models change with different economic policies, Wu and Chen (2001) suggest that the use of a regime-switching model, which could allow for economic policy to differ in times of strong depreciation and appreciation, may play a part in

better determining the effects of intervention. Moreover, the threshold model owns another attractive advantage. The objectives of China's central bank may differ before and after the 2008 financial crisis; that is, the effects of China's intervention may be different on yuan appreciation or depreciation. The threshold autoregressive model can capture this kind of change. Therefore, our application of the model here represents a contribution to the literature.

In this chapter, we first use Hansen's model-based bootstrap procedure (Hansen, 1999) to determine the number of regimes in the whole sample and three sub-samples. Then, Tsay's (1989) arranged autoregression method is used to get the order of the lag structure (p) for the AP model and the optimal delay parameter, and Chan's (1993) test is applied to obtain the threshold value and the smallest residual sum of squares (RSS). Because there are three regimes in the whole time period, two regimes in the first and third sub-samples, and one regime in the second sub-sample, we estimate the triple-threshold GARCH model, following Chen et al. (2010), the double threshold GARCH model introduced by Suardi (2008) and Utunomiya (2013), and the linear GARCH model (Hoshikawa, 2008), to test whether or not China's intervention (and its frequency) can move the USD/CNY exchange rate in the desired direction and reduce the exchange rate volatility in the whole sample and three sub-samples. This research is the first to use the triple-threshold GARCH model to test the effects of intervention (and its frequency) on the foreign exchange market. This is another main contribution of this chapter.

In recent years, there has been growing interest among researchers regarding the effects of central bank intervention on the emerging market economies (Agcaer,

2003; Domac and Mendoza, 2004; Guimaraes and Karacadag, 2004; Herrera and Ozbay, 2005; Akinci et al., 2006). Among the emerging economies China has potentially huge global impact, and as such has been the focus of great international concern. However, despite China maintaining an active intervention policy and being closely watched from around the globe, there is a surprising absence of studies of the country's central bank intervention. This research aims to fill that critical void.

This chapter aims to achieve a better understanding of China's intervention by investigating the effects of intervention and intervention frequency on exchange rate movements and volatility. It concentrates on the central parity rate (CPR) intervention and central bank (CB) intervention, the results of which are obtained from Chapters 4 and 5, and on the frequency of CPR and CB intervention, calculated by dividing the number of intervention days by one calendar year. Previous studies on central bank intervention have paid scant attention to the effect of intervention frequency,¹³ and there are no studies on intervention frequency in the emerging markets. This research extends the literature on intervention frequency to consider the case of China.

The target sample period covers 8 years, from 22 July, 2005 to 22 July, 2013. During this period, the Chinese exchange rate regime changed twice: on 14 July, 2008 it shifted from being managed 'with reference to a basket of currencies' to being pegged to the USD, while on 23 June, 2010 it reverted to the managed float system. In both cases, the changes can be explained as resulting from the 2008 financial

¹³ Fatum (2002), Hoshikawa (2008) and Utsunomiya (2013) are exceptions.

crisis. Hence, the sample period offers a good opportunity window for us to observe changes of effects of intervention and intervention frequency following financial crisis and regime changes.

Through applying the triple-threshold GARCH model in the whole sample, this thesis finds that both CPR and CB interventions support the leaning-against-the-wind hypothesis, but effects of CPR intervention on the exchange rate level happen when the yuan appreciates, and effects of CB intervention happen when the yuan depreciates. Compared with the results of Hoshikawa (2008), this chapter further finds that low-frequency CPR intervention has effects on the exchange rate level and high-frequency intervention reduces exchange rate volatility only when the yuan appreciates. In addition, the empirical results suggest that China's intervention increases the exchange rate volatility. Furthermore, based on the numbers of intervention and intervention frequency coefficients, we suggest that CPR intervention and CPR intervention frequency have stronger effects on the RMB exchange rate level than do CB intervention and frequency, and that the effects of CPR intervention on the exchange rate volatility are larger than the effects of CB intervention, but the effects of CPR intervention frequency are less than those of CB intervention frequency.

With regard to the time-varying effects of China's intervention before, during and after the 2008 financial crisis, the empirical evidence suggests that the objectives of intervention are different before and after the financial crisis. More specifically, before the financial crisis the objective of the PBOC was to offset the effects of exchange rate appreciations, but after the crisis interventions have a large influence

on the foreign exchange market when the RMB exchange rate depreciates. According to the results for during the financial crisis period, only CB intervention could impact the exchange rate return, and only high-frequency of CB intervention could impact volatility in the desired way. The results for CPR intervention frequency are contrary to the hypotheses, which assume negative signs of frequency variables.

The rest of this chapter is organized as follows. Section 6.2 presents a review of related literature. Section 6.3 discusses the data used in the study. Section 6.4 determines the number of regimes, and estimates threshold models for the effects of China's intervention. Section 6.5 reports the effects of China's intervention (and its frequency) derived from these threshold models. Section 6.6 presents a discussion of the findings.

6.2 Related Literature

Amid the growing literature on the efficacy of foreign exchange intervention, some studies test the influence of central bank intervention on the level and volatility of exchange rates based on transmission channels (Dominguez, 1987; Ghosh, 1992; Lewis, 1995; Catte et al., 1994; Huang, 2007). Other researches investigate the intervention effects without considering any transmission channel. From the late 1980s, the direct approaches, such as multi-variate GARCH frameworks, became the most popular to test the effects of intervention on the level and volatility of exchange rates. Using official data from April 1991 to March 2001, Ito (2002) studies Japanese intervention effects on the level of the exchange rate, but does not

consider the volatility effect. Using the structural approach to determining the effects of intervention, Disyatat and Galati (2007) apply the instrumental variable (IV) method to show that in the context of the Czech economy, intervention has weakly significant impacts on the spot rate and the risk reversal. The work reveals that the Czech monetary authorities will intervene when the speed of koruna appreciation accelerates. Kearns and Rigobon (2005) calculate that a US \$100 million purchase of Australian dollars by the Reserve Bank of Australia would be related with an appreciation of 1.3 - 1.8%, while the same size of purchase of yen by the Bank of Japan would appreciate the yen by only 0.2%. Through estimating a simultaneous equations model, i.e. the GMM approach, Hillebrand et al. (2009) obtain the result that Japanese intervention was unsuccessful during the period 1991-1995. From 1995 to 1998, Japanese intervention could move the yen/dollar exchange rate in the desired direction, but the authors do not find evidence of successful influence on volatility. For the period 1998-2004, there is strong evidence of a decrease in volatility, while the return to the yen/dollar exchange rate is not influenced by Japan's official intervention. Unlike previous studies, Kurihara (2013) considers both market communication and sterilized intervention. The results from the OLS and GMM models show that the Bank of Japan uses intervention to prevent excessive appreciation of the yen, and to promote export and expansion of the economy.

Some research considers frequency and asymmetric volatility when testing the effects of interventions. Hoshikawa (2008) examines the effects of central bank intervention frequency on the foreign exchange market. He suggests that intervention frequency has two different effects. First, high frequency intervention

stabilizes the exchange rate by decreasing exchange rate volatility. Second, compared to high frequency intervention, low frequency intervention has a larger effect on the exchange rate level. Utsunomiya (2013) considers periods of nonlinearity, which cannot be captured by standard volatility models such as the GARCH model. He finds that high-frequency interventions reduce volatility more strongly during periods of yen appreciation. Suardi (2008) also uses the DTGARCH model to study the effects of Japanese and US interventions from 1991 to 2003. He finds that interventions by the Bank of Japan and the Federal Reserve are more effective in changing the direction of the exchange rate movements and in reducing volatility in a regime when the exchange rates are severely misaligned. There is also evidence that in such a regime a negative return of exchange rate elicits higher levels of volatility than a positive return of equal magnitude. In addition, the presence of asymmetric volatility in exchange rate returns may be a result of active central bank intervention.

There is a lack of quantitative analysis in the literature on the effects of China's interventions. The studies to date focus on monthly data and simple VAR and GARCH approaches (Liu, 2010; Tian et al., 2012; Gao et al., 2013).

6.3 Data Descriptions

6.3.1 Measures of Foreign Exchange Intervention

In this chapter, we focus on CB intervention and CPR intervention. The effects of oral intervention are tested in the next chapter. Because the PBOC does not publish

the intervention data directly, we need to find proxies of the data. As explained in Chapter 4, we collect the CB intervention data from the newswire reports supplied by Factiva and Reuters China. With regard to the CPR intervention data, as explained in Chapter 5 we use as our proxy the CPR intervention ratio, which compares the central parity with the equilibrium USD/CNY exchange rate estimated by the IFV approach.

6.3.2 Data Description and Statistics

This section describes the dataset used in the empirical part of this research. First, we describe how to glean the data on intervention, USD/CNY exchange rates in domestic foreign exchange markets, interest rate spread, and stock price index, and how to calculate returns and realized volatility of RMB exchange rate. Then, we describe the summary statistics of the dataset and check the correlation between exchange rate return, realized volatility, the CB intervention and the CPR intervention.

The Dataset

The main time series used in this research are daily USD/CNY exchange rate and daily intervention time series. The sample period covers 8 years, from 22 July, 2005 to 22 July, 2013, with a total 2087 transaction days excluding official holidays. The reason for choosing this target sample period is that 22 July, 2005 was the first day of the new managed floating exchange rate regime implemented by the PBOC. From

that date, the RMB exchange rate value became increasingly based on ‘market supply and demand’ (Goldstein and Lardy, 2009); however, at the same time, the PBOC guided the rate towards the equilibrium level, and therefore was still actively managing the RMB currency. In this chapter, we analyse three sub-sample periods: 22 July, 2005 to 14 July, 2008; 15 July, 2008 to 22 June, 2010, and 23 June, 2010 to 22 July, 2013. On 15 July, 2008, in response to the global financial crisis, the managed float ‘with reference to a basket of currencies’ was suspended and the exchange rate changed to a USD peg, while on 23 June, 2010 it reverted to a managed float system. An additional reason for this choice of sub-samples is that the returns and volatility movements of the RMB exchange rate are in three stages (details in the next section). By testing these three sub-sample periods, we can identify whether the effects of China’s intervention over this eight-year period are time-varying.

The original data were collected from four major sources. First, the CB intervention information was obtained from newswire reports supplied by Factiva¹⁴ and Reuters China.¹⁵ Second, the USD/CNY exchange rate in the domestic foreign exchange market, MSCI China index, China Shibor overnight interest rate, and US Federal Funds rate were gleaned from Bloomberg. This chapter uses the closing-price of RMB exchange rate on every working day, and calculates returns and volatility of RMB exchange rate using these data (details of calculation for returns and volatility are in the next section). Third, we downloaded the data of central parity of RMB exchange rate from the State Administration of Foreign Exchange (SAFE) official

¹⁴ Factiva belongs to the Dow Jones Reuters Business Interactive LLC, formerly the Dow Jones interactive. Website: <http://www.dowjones.com/factiva/>, last accessed on 28th November 2013.

¹⁵ Reuters China: <http://cn.reuters.com/>, last accessed on 28th November 2013.

website.¹⁶ Finally, the USD/CNY exchange rate in the US market, which is needed to calculate the CPR intervention index, was downloaded from the Board of Governors of the Federal Reserve System website.¹⁷ All of the CPR and CB intervention data, central parity data, the RMB exchange rate data, MSCI China index data, and interest rate spread data are daily data.

Following Hoshikawa (2008), we use a calendar year moving average measure of intervention frequency, π_t , calculated by dividing the number of intervention days by one calendar year. Table 6.1 reports variables π_t^{CPR} and π_t^{CB} . Numbers of frequency variables during the financial crisis (2008 to 2010) are smaller than in other periods. In addition, there are far more CPR intervention days than CB intervention days, indicating that the PBOC uses CPR intervention as the main intervention tool.

¹⁶ State Administration of Foreign Exchange: <http://www.safe.gov.cn/>, last accessed on 30th November 2013.

¹⁷ Board of Governors of the Federal Reserve System: http://www.federalreserve.gov/releases/h10/summary/indexb_b.htm, last accessed on 14th January 2014.

Table 6.1 Number of Intervention Days per Year

Year	Business days	CPR intervention days	CB intervention days	π_t^{CPR}	π_t^{CB}
2005	116	116	63	0.7155	0.5431
2006	260	259	82	0.5615	0.3154
2007	261	260	82	0.6782	0.3142
2008	262	261	71	0.7176	0.2710
2009	261	260	29	0.2184	0.1111
2010	261	260	53	0.4061	0.2031
2011	260	260	96	0.6692	0.3692
2012	261	260	110	0.4291	0.4215
2013	145	143	75	0.2345	0.5172

Notes: π_t is the number of intervention days divided by the number of business days (π_t^{CPR} is for CPR intervention and π_t^{CB} is for CB intervention). Business days in 2005 are calculated for the period from July 22 to December 30, and business days in 2013 are calculated for the period from January 01 to July 22.

RMB Exchange Rate Returns and Volatility

Compared to the nominal exchange rate of the RMB in relation to the US dollar, return on the exchange rate is more attractive to researchers, because the return is used to decide whether interventions push the exchange rate in the desired direction.

There are two definitions of exchange rate return in mathematics. The arithmetic return rate is defined as follows:

$$R_{1,t} = \frac{S_t - S_{t-1}}{S_{t-1}} \quad (6.1)$$

The geometric approach to calculate the return on exchange rate is defined as follows:

$$R_{2,t} = \text{Log} \left(\frac{S_t}{S_{t-1}} \right) \quad (6.2)$$

where $R_{1,t}$ and $R_{2,t}$ are returns on exchange rate, and S_t and S_{t-1} are the nominal spot exchange rate and lagged exchange rate respectively. This research employs the geometric approach, as it is the most used approach in the relevant literature. In addition, the geometric return allows for linking time-discrete models and time-continued models.

GARCH type models, such as GARCH (p,q) (Kim,1998; Akinci et al., 2006), GARCH-M (p,q) (Engle, Lilien and Robins, 1987), and EGARCH (p,q) (Nelson,1991; Hoshikawa, 2008), are helpful to estimate the conditional volatility of daily exchange rate changes. In this research, we use the asymmetric GARCH modelling strategy (Glosten et al., 1993; Suardi, 2008) to obtain the conditional volatility. The equation for the conditional volatility is defined as follows:

$$r_t = c_0 + \sum_{k=1}^p \theta_k r_{t-k} + \alpha_0 (i_t - i_t^*) + \alpha_1 S T_t + (\beta_0 + \beta_1 \pi_t^{CPR}) CPR_t + (\omega_0 + \omega_1 \pi_t^{CB}) CB_t + \mu_t$$

$$h_t = \Phi_0 + \Phi_1 h_{t-1} + \Phi_2 \varepsilon_{t-1}^2 + \lambda_0 |CPR_t| + \lambda_1 |CB_t| + \tau_0 \pi_t^{CPR} + \tau_1 \pi_t^{CB} + \varphi \eta_{t-1}^2 \quad (6.3)$$

where r_t denotes the log daily returns on RMB exchange rate at time t ; $(i_t - i_t^*)$ means the spread between the domestic and US interest rate; ST_t is the MSCI China index, which denotes the returns on the Chinese stock market; CPR_t and CB_t are intervention variables; π_t is the intervention frequency variable; ε_t is the residual of the mean equation; h_t is the conditional variance of the exchange rate, and $\varphi \eta_{t-1}^2$ is the asymmetric component. The results for the asymmetric GARCH (1,1) model are given in Table B in the Appendix.

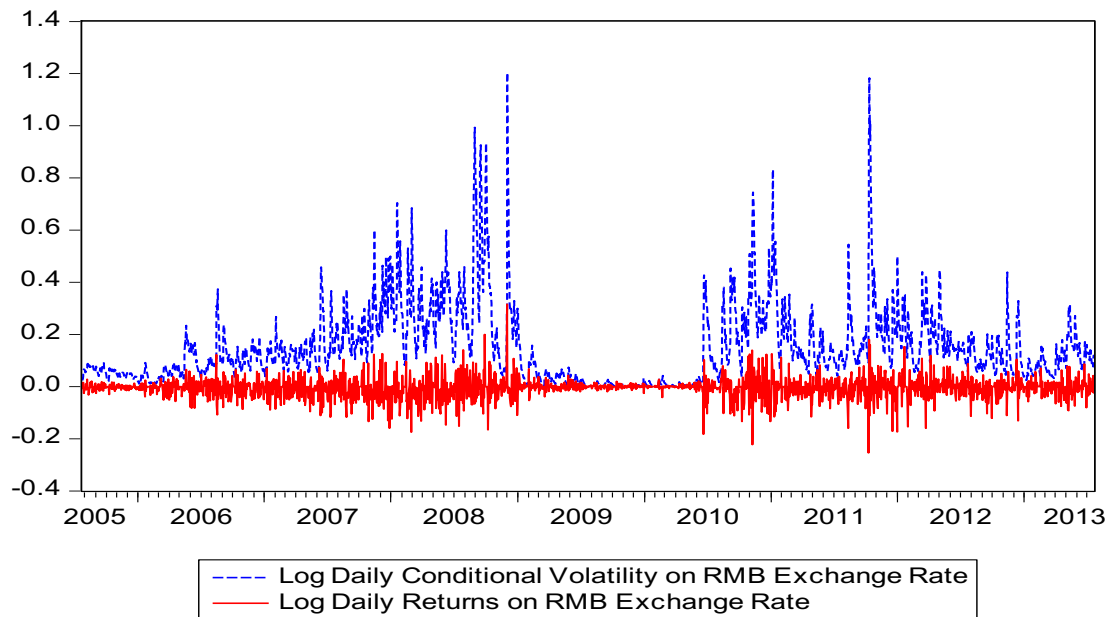


Figure 6.1 Log Daily Conditional Volatility and Log Daily Returns on RMB Exchange Rate

The movements of log daily conditional volatility (dotted line) and log daily returns (solid line) on RMB exchange rate are shown in Figure 6.1 above. As can be seen

from the figure, conditional volatility and returns movements have similar characteristics. The figure reveals three stages. Based on these stages, the total data sample is divided into three sub-samples. In addition, economic sense tells us that changes in exchange rate returns have important effects in terms of changing central bank intervention behaviour (Kragler and Kugler, 1993). First, from July 2005 to July 2008, the fluctuation of RMB exchange rate returns is highly volatile, and log volatility is also high. The large fluctuation is explained by the fact that, prior to the 2005 exchange rate regime change, there had been a long period during which the Chinese government had depressed the exchange rate level; therefore, large fluctuation was needed in order to achieve the equilibrium level. Second, from July 2008 to June 2010 fluctuation of the RMB exchange rate was relatively small. During this stage, because of the effects of global financial crisis, the RMB currency was fixed to the US dollar; that is, the exchange rate regime was a pegging system. Therefore, the fluctuation of exchange rate returns and volatility are around zero; in other words, exchange rate level and volatility movements are stable. Finally, because the PBOC began to implement a new ‘managed floating’ exchange rate policy on 23 June, 2010 (PBOC, 2010),¹⁸ the RMB exchange rate started to fluctuate more widely. Both returns and realized volatility returned to large fluctuation in the final period.

Data Statistics

Table 6.2 Summary Statistics

¹⁸ 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).

	Obs.	Mean	Std. dev.	Skewness	Excess Kurtosis
Summary statistics					
ΔS_t	2087	-0.0058	0.0407	-0.1360	8.2275
CPR_t	1077	0.00008	0.0078	4.6395	115.6611
CB_t	661	0.03881	0.5616	0.0116	3.1557
π_t^{CPR}	2087	0.9924	0.0617	-15.9985	257.5933
π_t^{CB}	2087	0.3167	0.1205	0.0480	2.4616
	ΔS_t	CPR_t	CB_t	π_t^{CPR}	π_t^{CB}
Cross-correlation					
ΔS_t	1.0000				
CPR_t	0.0206	1.0000			
CB_t	0.2226	0.0193	1.0000		
π_t^{CPR}	-0.0062	0.0142	0.0302	1.0000	
π_t^{CB}	0.0029	0.0244	0.1067	-0.0013	1.0000

Notes: ΔS_t is 100 times log exchange rate return, CPR_t is the CPR intervention, CB_t is the CB intervention, π_t^{CPR} is the CPR intervention frequency, and π_t^{CB} is the CB intervention frequency.

Table 6.2 presents the descriptive statistics for the RMB exchange rate, CPR intervention, CB intervention, CPR intervention frequency and CB intervention frequency of the China foreign exchange market. The mean of exchange rate returns for the overall sample is negative, indicating that the yuan appreciates against the USD in these years. The kurtosis of ΔS_t is 8.228, which is larger than 3 using normal distribution; that is, the distribution is fat-tailed. The changes in daily exchange rate volatility may have this kind of distribution. The generalized autoregressive conditional heteroscedasticity (GARCH) model is generally used in the case of volatility change. Moreover, we find evidence of negative skewness (-0.136) in the USD/CNY exchange rate in the overall sample period. Table 6.2 also shows that both types of intervention and CB intervention frequency are positively correlated with log exchange rate changes, but CPR intervention frequency has a negative correlation.

6.4 Modelling Effects of FX Intervention in China

In this section, we estimate and explain the threshold autoregressive models, which are double threshold GARCH (DTGARCH) (Suardi, 2008; Utunomiya, 2013) and triple threshold GARCH models (Chen et al., 2010). In order to determine the number of regimes in threshold autoregressive models, we use Hansen's model-based bootstrap procedure (Hansen, 1999). Then, Tsay's (1989) arranged autoregression method is helpful to get the order of the lag structure (p) for the AR model and the optimal delay parameter d^* . Finally, the threshold value (γ) and the smallest residual sum of squares (RSS) are obtained by Chan's (1993) test.

6.4.1 Determining the Number of Regimes

Similar to Strikholm and Terasvirta (2006) and Utsunomiya (2013), the Autoregressive (AR) model is written as:

$$r_t = c + \sum_{k=1}^p \theta_k r_{t-k} + \mu_t \quad (6.4)$$

where r_t is the log return of the USD/CNY exchange rate at time t . Hansen's (2000) m -regime threshold model allows the parameter vector θ in the AR model (model 6.4) to change m times based on the value of the threshold variable q_t . A two-regime threshold model can be formulated as follows:

$$r_t = (c_{10} + \sum_{k=1}^p \theta_k^{(21)} r_{t-k}) I(r_{t-d^*} \leq \gamma) + (c_{20} + \sum_{k=1}^p \theta_k^{(22)} r_{t-k}) I(r_{t-d^*} > \gamma) + \mu_t \quad (6.5)$$

where $I(\cdot)$ denotes the indicator function, which takes the value one when the condition in the brackets is satisfied and zero otherwise, and γ is the threshold value.

In addition, a triple-threshold model can be formulated as follows:

$$r_t = (c_{10} + \sum_{k=1}^p \theta_k^{(31)} r_{t-k}) I(r_{t-d^*} \leq \gamma_1) + (c_{20} + \sum_{k=1}^p \theta_k^{(32)} r_{t-k}) I(\gamma_1 < r_{t-d^*} \leq \gamma_2) + (c_{30} + \sum_{k=1}^p \theta_k^{(33)} r_{t-k}) I(r_{t-d^*} > \gamma_2) + \mu_t \quad (6.6)$$

If the independent variables consist only of lags of dependent variable, the model is named a threshold autoregressive (TAR) model. If the threshold variable (r_{t-d^*}) is one of the lagged dependent variables, the model becomes a self-exciting threshold autoregressive (SETAR) model. Therefore, the models (6.5) and (6.6) are SETAR models.

Hansen's model-based bootstrap procedure is a sequential procedure, in which sequential testing is carried out by a likelihood ratio (LR) statistic whose distribution is bootstrapped. The procedure is implemented as follows. First, considering the linear and two-regime threshold models, testing the one-regime model against the two-regime model is equivalent to testing the null hypothesis:

$$H_0: \theta_k = \theta_k^{(21)} = \theta_k^{(22)} \quad (6.7)$$

Hansen (1999) estimates a test statistic of:

$$F_{12} = T \frac{S_1 - S_2}{S_2} \quad (6.8)$$

where S_1 is the sum of squared residuals from linear square (LS) estimation of the linear model (6.4), S_2 is the sum of squared residuals from the two-regime model (6.5), and T is the sample size. If the F_{12} is significant, it rejects the null hypothesis. That is, the nonlinear model is a better specification than the linear model. If not, the linear model is better.

Second, similar to step one, testing the one-regime model against the three-regime model is equivalent to testing the null hypothesis:

$$H_0: \theta_k = \theta_k^{(31)} = \theta_k^{(32)} = \theta_k^{(33)} \quad (6.9)$$

The test statistic is:

$$F_{13} = T \frac{S_1 - S_3}{S_3} \quad (6.10)$$

Finally, testing the two-regime model against the three-regime model is equivalent to testing the null hypothesis:

$$H_0: \theta_k^{(21)} = \theta_k^{(22)} = \theta_k^{(31)} = \theta_k^{(32)} = \theta_k^{(33)} \quad (6.11)$$

The test statistic is:

$$F_{23} = T \frac{S_2 - S_3}{S_3} \quad (6.12)$$

When the thresholds are known, F is asymptotically equivalent to the usual F statistic. However, because the thresholds are unknown and not identified under the null hypotheses, F follows an unknown asymptotic distribution. Bootstrapping methods are relied on to compute the p-values with and without the conditional heteroscedasticity assumption.

Under the homoscedastic error assumption, a set of bootstrap errors $\tilde{\mu} = \{\tilde{\mu}_t \mid t = 1, \dots, T\}$ is gained by randomly drawing T times with replacement from the OLS residuals $\mu = \{\mu_t \mid t = 1, \dots, T\}$ of the linear model (6.4). A set of data on the dependent variable is then generated by:

$$\tilde{r}_t = \hat{c} + \sum_{k=1}^p \hat{\theta}_k \tilde{r}_{t-k} + \tilde{\mu}_t \quad (6.13)$$

where $\{\hat{c}, \hat{\theta}_1, \dots, \hat{\theta}_k\}$ are OLS estimates of model (6.4). Substituting \tilde{r}_t for r_t , all the m-regime (m=1,2,3) models are re-estimated to provide one value of \tilde{F} defined as:

$$\tilde{F}_{12} = T \frac{\tilde{S}_1 - \tilde{S}_2}{\tilde{S}_2} \quad (6.14)$$

$$\tilde{F}_{13} = T \frac{\tilde{S}_1 - \tilde{S}_3}{\tilde{S}_3} \quad (6.15)$$

$$\tilde{F}_{23} = T \frac{\tilde{S}_2 - \tilde{S}_3}{\tilde{S}_3} \quad (6.16)$$

where \tilde{S} is the sum of squared residuals from the linear and nonlinear models with bootstrapped data. Out of 1,000 replications, the proportion of \tilde{F} greater than F is the approximate p-value.

Under the heteroscedastic error assumption, the procedure is a little more complicated because we have to impose heteroscedasticity on the bootstrap errors $\tilde{\mu}$. First, each element of $\tilde{\mu}$ is divided by an estimate of the conditional standard

deviation $\sqrt{\hat{h}_t}$ to gain a set of homoscedastic errors:

$$\tilde{\mu} = \left\{ \tilde{\mu}_t \mid \tilde{\mu}_t = \frac{\tilde{\mu}_t}{\sqrt{\hat{h}_t}}, t = 1, \dots, T \right\} \quad (6.17)$$

The conditional variance estimate \hat{h}_t is obtained as a fitted value from an auxiliary regression of μ_t^2 on $w_t = \{1, r_t r_t', r_{t-1}^2, \dots, r_{t-k}^2\}$. Let $\hat{\delta}$ denote that OLS estimates obtained from such a regression.

Now we draw randomly from $\tilde{\mu}$. The t-th heteroscedastic bootstrap error is:

$$\tilde{\mu}_t = \tilde{\mu} \sqrt{\tilde{h}_t} \tag{6.18}$$

where $\tilde{h}_t = \tilde{w}_t \tilde{\delta}$ and $\tilde{w}_t = \{1, r_t r_t', \tilde{r}_{t-1}^2, \dots, \tilde{r}_{t-k}^2\}$. Once the value of $\tilde{\mu}_t$ is gained, the value of \tilde{r}_t is calculated using model (6.7). It is important to note that $\tilde{h}_t \neq \hat{h}_t$ and $w_t \neq \tilde{w}_t$. The rest of the bootstrap procedure is the same as in the homoscedastic case.

Table 6.3 Hansen's Model-Based Bootstrapping Test

	F-statistic	p-value	
		Homoscedastic	Heteroscedastic
Whole sample	F_{12} 61.711	0.000	0.067
2005:07:22- 2013:07:22	F_{13} 101.708 F_{23} 38.842	0.000 0.011	0.060 0.061
First sub-sample	F_{12} 62.920	0.000	0.041
2005:07:22- 2008:07:14	F_{13} 103.210 F_{23} 37.232	0.000 0.024	0.036 0.178
Second sub-sample	F_{12} 49.023	0.000	0.424
2008:07:15- 2010:06:22	F_{13} 72.984 F_{23} 21.802	0.279 0.517	0.515 0.731
Third sub-sample	F_{12} 74.288	0.000	0.066
2010:06:23- 2013:07:22	F_{13} 103.401 F_{23} 26.002	0.005 0.747	0.065 0.897

Table 6.3 presents the results of applying Hansen's model-based bootstrapping approach for the total sample and three sub-samples. For the total sample, the test statistic F_{12} for testing the linear model versus the two-regime model is 61.711. The bootstrap p-values are calculated as the proportion of those bootstrap simulations out of 1000 replications that have F-statistic larger than 61.711. Under the assumption of homoscedastic errors, the p-value is zero. Therefore, we reject (fail to accept) the null hypothesis of linearity in favour of a two-regime threshold nonlinearity at 1% level. In addition, under the assumption of heteroscedastic errors, the p-value is 0.067 and we still reject the null of the linear model. With regard to the three-regime alternative, the F_{13} is 101.708. As with the F_{12} , the p-value is zero under the homoscedasticity and heteroscedasticity assumptions. Therefore we reject the null of linearity. The F_{23} is econometrically significant with both the homoscedasticity assumption and the heteroscedasticity assumption. Therefore, we reject the null of linearity with both assumptions.

For the first sub-sample, F_{12} and F_{13} are clearly significant under both homoscedasticity and heteroscedasticity assumptions. F_{23} is not significant under the heteroscedasticity assumption. Since heteroscedasticity seems quite likely in this data (Hansen, 1999), we conclude that we cannot reject the hypothesis of linearity. For the second sub-sample, with the exception of the F_{12} under the homoscedasticity assumption, all the F statistics are not significant. The third sub-sample follows the same pattern as the first sub-sample. That is, F_{12} and F_{13} are significant under both homoscedasticity and heteroscedasticity assumptions. However, F_{23} is not significant under either assumption.

In summary, we should estimate the three-regime threshold model in the total sample, the two-regime model in the first sub-sample, the linear model in the second sub-sample, and the two-regime model in the third sub-sample. The results of the number of regimes are the same as the results in the figure of log RMB exchange rate return. That is, the second sub-sample is so stable that there is just one regime.

6.4.2 The AR Order, Optimal Delay Parameter, Threshold Value and RSS

Tsay's (1989) arranged autoregression method is applied to determine the existence of threshold nonlinearity in the mean of USD/CNY exchange rate return. This also tests the robustness of the results of Hansen's model-based bootstrap method. A core part of Tsay's (1989) test procedure is choice of an appropriate AR order followed by the delay parameter d . As the null of a linear model could be wrongly rejected owing to the omission of serial correlation, it is important to fit the appropriate AR model in the preliminary stage (Kilian and Taylor, 2003). The procedure for Tsay's (1989) test is as follows:

First, before running the arranged autoregression, we apply the Akaike information criterion (AIC) to determine the order of lag structure (p) for the AR model (6.4). Breusch (1978) and Godfrey (1978) have confirmed the absence of serial correlation in the residuals for lag orders up to order 12. Therefore, we use order 12 ($k=12$) in the AIC step.

Then, we arrange variables based on the value of r_{t-1}, \dots, r_{t-k} . For instance, we place the smallest r_{t-1} first and the largest r_{t-1} last. An arranged autoregression is estimated:

$$r_t^* = c^* + \sum_{k=1}^p \theta_k^* r_{t-k}^* + \mu_t^* \quad (6.19)$$

Then, we use the arranged autoregression to calculate the standardized predictive residuals:

$$\hat{e}_s = w_0 + \sum_{k=1}^p w_k r_{s-k} + \varepsilon_s \quad (6.20)$$

where $s = m + 1, \dots, T - d - h + 1$, T is the sample size, $m = \left(\frac{T}{10}\right) + p$ and $h = \max\{1, p - d + 1\}$. For a given lag structure of AR model, the optimal delay parameter d^* can be obtained by computing:

$$\hat{F}(p, d^*) = \max_{d \in D} \hat{F}(p, d) \quad (6.21)$$

where $D = \{1, 2, \dots, p - 1\}$ and \hat{F} is the calculated F-statistic given by $\hat{F} = \frac{(\sum \hat{e}_t^2 - \sum \hat{\varepsilon}_t^2)/(p+1)}{\sum \hat{\varepsilon}_t^2 / (T-d-m-p-h)}$. Here, \hat{e}_t is the standardized predictive residuals from the model (6.20), and $\hat{\varepsilon}_t$ is the resulting residuals from regressing the model (6.21). The test statistic follows an F-distribution with $(p+1)$ and $(T-d-m-p-h)$ degrees of freedom. This step can select the value of the delay parameter which gives the most significant result in testing for nonlinearity.

After choosing the lag structure and the delay parameter, we use Chan's (1993) method to estimate the threshold value (γ , γ_1 , and γ_2) by using ordinary least squares to run the regressions (6.4) and (6.5). In the previous section, we have established that there are three regimes in the total sample, two regimes in the first and third sub-samples, and one regime in the second sub-sample, which means we need to get γ_1 , and γ_2 in the total sample and γ in the first and third sub-samples.

In order to ensure the threshold value is meaningful, the exchange rate return series have to actually cross the threshold. In other words, γ , γ_1 , and γ_2 must lie within the maximum and minimum range of USD/CNY exchange rate return series. Following Chan (1993), we exclude the highest and lowest 15% (τ) values to ensure there are an adequate number of observations on each side of the threshold. For the overall sample of 2087 observations, we exclude the highest and lowest 15% of the observations. The evidence for these threshold effects is stronger with $\tau = 15\%$ as reported in Table 6.4. The 15% τ has the most significant F -test. For the sub-samples, we exclude the highest and lowest 20% of the observations. The consistent estimate of the threshold is the threshold value used in equations (6.3) and (6.4) that produces the smallest residual sum of squares (RSS). The minimum RSS can locate the threshold value.

Table 6.4 P-Values for Different Restrictions on Minimum Sample Size

	F_{12}	F_{13}	F_{23}
5%	88.057(0.000)	145.334(0.000)	61.808(0.015)
10%	108.856(0.000)	145.334(0.000)	33.987(0.075)
15%	61.711(0.000)	101.708(0.000)	38.842(0.011)
20%	147.492(0.000)	180.237(0.000)	40.607(0.190)

Notes: $F_{i,j}$ is the test statistic for i-regimes against j-regimes. p -values are in parentheses.

Table 6.5 Threshold Test and Parameter Estimates

	AIC-based p lag	d^*	Tsay's threshold test	γ	Min RSS
Total sample 22/07/2005-22/07/2013	1	7	$F_{(8,2064)} = 534.891$ (0.000)	$\gamma_1 = -0.04157$ $\gamma_2 = 0.02345$	$RSS_1 = 0.00151$ $RSS_2 = 0.0176$
First sub-sample 22/07/2005-14/07/2008	2	1	$F_{(2,771)} = 250.419$ (0.000)	-0.01826	0.003
Second sub-sample 15/07/2008-22/06/2010	1	1	$F_{(2,386)} = 564.140$ (2.701)	N.A.	N.A.
Third sub-sample 23/06/2010-22/07/2013	1	1	$F_{(2,799)} = 432.841$ (0.000)	0.000698	0.00499

Notes: The value p estimated by AIC is the best lag length for the exchange rate return series; d^* is the threshold delay parameter; Tsay's (1989) threshold test has a null of an AR model against the alternative of a threshold AR model. The numbers in parentheses are p-values. Chan's (1993) test gives the threshold value (γ) and the minimum RSS.

Table 6.5 reports the results for Tsay's (1989) threshold nonlinearity test and the parameter estimates comprising the lag length for the AR model, the delay parameter and the threshold estimate with its corresponding minimum RSS for the whole sample and three sub-samples. Value 1 of p for the total sample, second sub-sample and third sub-sample is chosen the AIC, and value 2 for the first sub-sample. The value p is the best lag length for the exchange rate return series. The overall sample chooses a threshold delay parameter (d^*) of 7, all of sub samples choose 1. From Tsay's threshold test, we obtain that the second sub-sample possesses linearity because the F for the second sub-sample accepts the null hypothesis of linearity. This provides robustness for the results of Hansen's model-based bootstrap method. The estimated threshold values for the overall sample are -0.042 and 0.023, with the minimum RSS 0.0015 and 0.018. In addition, the first and third sub-samples have threshold values -0.009 and 0.003, with the minimum RSS 0.003 and 0.005 respectively. The positive threshold values suggest that when the magnitude of Chinese yuan depreciation against the US dollar exceeds these positive values, there would be a change in process governing the exchange rate return dynamics. Similarly, the negative threshold values indicate that when appreciation of USD/CNY exchange rate exceeds these negative values there would also be a change in the process governing the exchange rate return dynamics.

After choosing the threshold in the conditional mean of USD/CNY exchange rate return dynamics, we then explore the location of the threshold in the conditional variance. Although the variance equation might have different threshold values compared with the threshold found for the conditional mean, with the exception of the double-threshold ARCH model, threshold estimation techniques have been

developed only for the conditional mean. Li and Li (1996) apply the iteratively weighted least squares method to model a double-threshold ARCH model. However, the generalization to a GARCH process is not straightforward and has never been shown in the literature. Therefore, we do not pursue the determination of a different threshold in the conditional variance for our models. Following Suardi (2008) and Utsunomiya (2013), we consider that the threshold in the mean of RMB exchange rate return governs the dynamics in its conditional variance. The estimation of the double threshold GARCH model is formulated as follows:

$$r_t = \begin{cases} c_{10} + \sum_{k=1}^p \theta_{1k} r_{t-k} + \mu_t & \text{if } r_{t-d^*} \leq \gamma \\ c_{20} + \sum_{k=1}^p \theta_{2k} r_{t-k} + \mu_t & \text{if } r_{t-d^*} > \gamma \end{cases}$$

$$\mu_t \sim N(0, h_t) \quad h_t = \begin{cases} \Phi_{10} + \Phi_{11} h_{t-1} + \Phi_{12} \varepsilon_{t-1}^2 & \text{if } r_{t-d^*} \leq \gamma \\ \Phi_{20} + \Phi_{21} h_{t-1} + \Phi_{22} \varepsilon_{t-1}^2 & \text{if } r_{t-d^*} > \gamma \end{cases} \quad (6.22)$$

Model (6.23) below is the triple-threshold GARCH model, specified as:

$$r_t = \begin{cases} c_{10} + \sum_{k=1}^p \theta_{1k} r_{t-k} + \mu_t & \text{if } r_{t-d^*} \leq \gamma_1 \\ c_{20} + \sum_{k=1}^p \theta_{2k} r_{t-k} + \mu_t & \text{if } \gamma_1 < r_{t-d^*} \leq \gamma_2 \\ c_{30} + \sum_{k=1}^p \theta_{3k} r_{t-k} + \mu_t & \text{if } r_{t-d^*} > \gamma_2 \end{cases}$$

$$\mu_t \sim N(0, h_t) \quad h_t = \begin{cases} \Phi_{10} + \Phi_{11} h_{t-1} + \Phi_{12} \varepsilon_{t-1}^2 & \text{if } r_{t-d^*} \leq \gamma_1 \\ \Phi_{20} + \Phi_{21} h_{t-1} + \Phi_{22} \varepsilon_{t-1}^2 & \text{if } \gamma_1 < r_{t-d^*} \leq \gamma_2 \\ \Phi_{30} + \Phi_{31} h_{t-1} + \Phi_{32} \varepsilon_{t-1}^2 & \text{if } r_{t-d^*} > \gamma_2 \end{cases} \quad (6.23)$$

Table 6.6 Unit Root Tests for Threshold Variables

Level	First-difference						
Entire period: 2005:07:22—2013:07:22							
ADF	-0.501	PP	-0.514	ADF	-48.583***	PP	-48.567***
Subsample1: 2005:07:22—2008:07:14							
ADF	-0.150	PP	-0.144	ADF	-23.059***	PP	-30.259***
Subsample2: 2008:07:15—2010:06:22							
ADF	-0.173	PP	-0.096	ADF	-25.432***	PP	-25.831***
Subsample3: 2010:06:23—2013:07:22							
ADF	-1.949	PP	-2.185	ADF	-12.161***	PP	-30.658***

Notes: *** significant at 1%, ** at 5%, * at 10% level.

Table 6.6 presents the stationarity property of the RMB exchange rate level and first difference of logarithm of the exchange rate in different periods. We perform the Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests. One critical requirement of the threshold model is that the threshold variable should be strictly stationary. If the threshold variable is non-stationary, hence there is no tendency for mean-reverting, the idea of switching over a limited number of regimes depending on the value of the threshold variable does not make much sense.¹⁹ From the results of the unit root tests, the null hypothesis of unit root for first difference of logarithm of the exchange rate is rejected in all periods.

¹⁹ For example, it is required to have some observations with $r_{t-d^*} \leq \gamma$ and other observations with $r_{t-d^*} > \gamma$. If r_{t-d^*} is a unit-root time series, it may be the case that $r_{t-d^*} > \gamma$ always after some time point, hence no more observations for regime 1.

6.4.3 Modelling China's Intervention

The threshold GARCH models have advantages in two main areas. First, recent studies prove that asymmetric volatility is present in the foreign exchange markets and show the importance of considering the asymmetry when analysing foreign exchange volatility (Brooks, 2001; Yang, 2006; Wang and Yang, 2009; Park, 2011). Results from Table 6.7 show that there is asymmetric volatility in China's foreign exchange market. The null hypothesis of equal variances of the RMB exchange rate returns on days of purchase versus days of sale CB interventions and high versus low CPR interventions is rejected. In addition, results from section 6.4.1 have given evidence of threshold nonlinearity in RMB exchange rate returns for the overall sample, and the first and third sub-samples. Compared to the linear model or GARCH model, the DTGARCH process estimated by Liu, Li and Li (1997) can capture both sign and size asymmetries in the average return, volatility level, mean reversion and volatility persistence, and can model the impact of intervention on the exchange rate level and volatility in each regime (Chen et al., 2010). In order to test the volatility asymmetry, we apply the asymmetric GARCH modelling strategy developed by Glosten et al. (1993). Second, the threshold autoregressive model can capture the changes of intervention effects when the yuan is appreciating or depreciating before and after the 2008 financial crisis. Considering these conditions, we estimate the triple-threshold GARCH model as follows:

$r_t =$

$$\begin{cases} c_{10} + \sum_{k=1}^p \theta_{1k} r_{t-k} + \alpha_{10}(i_t - i_t^*) + \alpha_{11} S T_t + (\beta_{10} + \beta_{11} \pi_t) Int_t + \mu_t & \text{if } r_{t-d^*} \leq \gamma_1 \\ c_{20} + \sum_{k=1}^p \theta_{2k} r_{t-k} + \alpha_{20}(i_t - i_t^*) + \alpha_{21} S T_t + (\beta_{20} + \beta_{21} \pi_t) Int_t + \mu_t & \text{if } \gamma_1 < r_{t-d^*} \leq \gamma_2 \\ c_{30} + \sum_{k=1}^p \theta_{3k} r_{t-k} + \alpha_{30}(i_t - i_t^*) + \alpha_{31} S T_t + (\beta_{30} + \beta_{31} \pi_t) Int_t + \mu_t & \text{if } r_{t-d^*} > \gamma_2 \end{cases}$$

$$h_t = \begin{cases} \Phi_{10} + \Phi_{11}h_{t-1} + \Phi_{12}\varepsilon_{t-1}^2 + \lambda_{10}|Int_t| + \tau_{10}\pi_t + \varphi_1\eta_{t-1}^2 & \text{if } r_{t-d^*} \leq \gamma_1 \\ \Phi_{20} + \Phi_{21}h_{t-1} + \Phi_{22}\varepsilon_{t-1}^2 + \lambda_{20}|Int_t| + \tau_{20}\pi_t + \varphi_2\eta_{t-1}^2 & \text{if } \gamma_1 < r_{t-d^*} \leq \gamma_2 \\ \Phi_{30} + \Phi_{31}h_{t-1} + \Phi_{32}\varepsilon_{t-1}^2 + \lambda_{30}|Int_t| + \tau_{30}\pi_t + \varphi_3\eta_{t-1}^2 & \text{if } r_{t-d^*} > \gamma_2 \end{cases} \quad (6.24)$$

where Int_t is the intervention variables for CPR or CB, π_t is the intervention frequency variables for CPR or CB, $E(\mu_t) = 0$, $\mu_t = \sqrt{h_t}z_t$, and z_t follows a Student's t-distribution with v degrees of freedom. The values for p and γ have been determined in section 6.4.2, above.

Table 6.7 Variance Equality Tests on the Exchange Rate Returns

	CPR intervention		CB intervention	
	Levene	Brown-Forsythe	Levene	Brown-Forsythe
Degrees of freedom	(4,2082)	(4,2082)	(3,2083)	(3,2083)
RMB_t	43.825(0.000)	33.809(0.000)	11.923(0.000)	7.627(0.000)

Notes: the null hypothesis is that the variance of currency return i on the days of intervention through purchases or high intervention is equal to the variance of currency return i on the days of intervention through sales or low intervention. The tests are conducted for the whole period from July 22, 2005 to July 22, 2013. p -values are in parentheses.

The interest rate differential, which is calculated by the spread between the China Shibor overnight rate (i_t) and the US Federal Funds rate (i_t^*), is used to capture the possible effects of the monetary policy action and local money market conditions on the RMB exchange rate (Kim and Sheen, 2002; Hassan, 2009). There are two hypotheses of correlation between interest rate differential and the exchange rate: a traditional view and a revisionist view. The traditional view claims that tight monetary policies may lead exchange rates to appreciate; that is, $\alpha_0 < 0$. High

interest rates that provide a higher rate of return for foreign investors may reduce capital flight and discourage speculative trends (Dekle et al., 2001). On the other hand, according to the revisionist view, an increase in interest rates has an adverse impact on exchange rates; that is, $\alpha_0 > 0$. For the advocates of this view (Furman and Stiglitz, 1998; Radelet and Sachs, 1998), contractionary monetary policies and high interest rates may result in capital outflows and exchange rate depreciation due to a financial crisis. The high interest rates are the cause of both financial crisis and a default probability that may weaken a national currency. ST_t denotes the returns on the MSCI China stock index. Similar to Bonser-Neal and Tanner (1996), we use the stock index as control variable to reflect the influence of economic or political events on the foreign exchange market. There are two contrasting hypotheses whereby exchange rate is expected to react to stock prices. In one, a rise in stock price leads to domestic currency depreciation (Ajayi and Mougoue, 1996). An increasing stock market is an indicator of an expanding economy, which is accompanied by higher inflation expectations. If higher inflation happens, foreign investors' demand for domestic currency drops and the currency depreciates, which is $\alpha_1 > 0$. The other hypothesis claims that if the stock market declines, the currency will depreciate. In markets with high capital mobility, it is capital flows, and not the trade flows, that determine the daily demand for currency. A decline in stock prices leads foreign investors to sell the financial assets they hold. This means the sign of α_1 will reverse. In the next section, the results from the models will decide which hypotheses of interest rate spread and stock price are suitable for China. Figures 6.2 and 6.3 show the movements of interest rate spread and stock price with RMB exchange rate in the whole period.

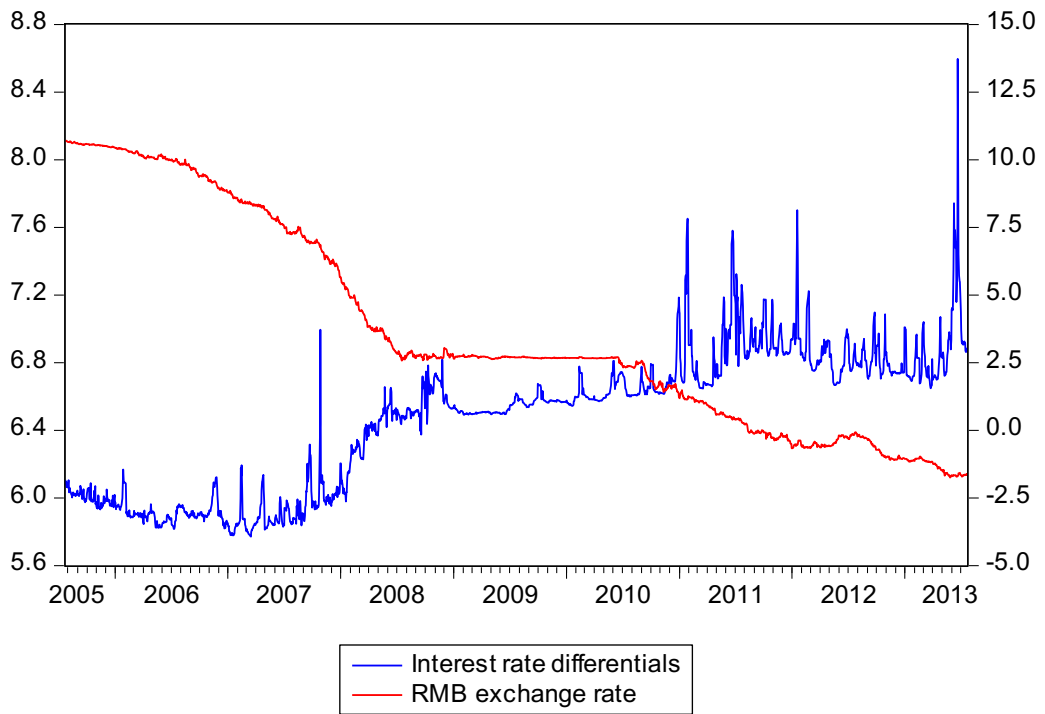


Figure 6.2 Movements of Interest Rate Differentials and the RMB Exchange Rate

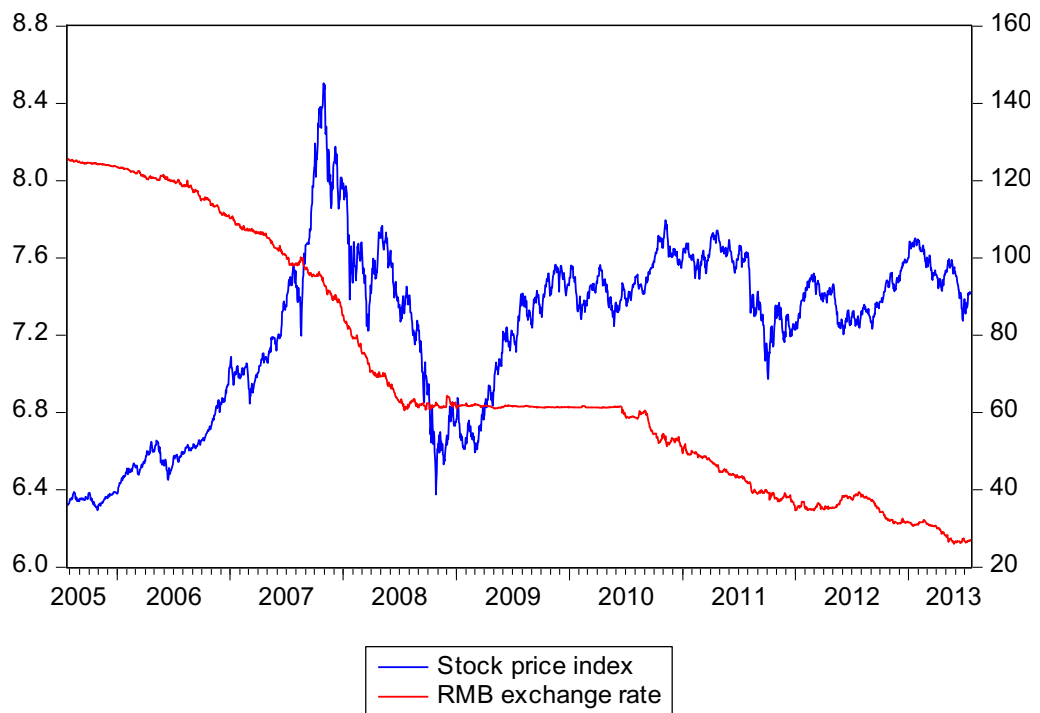


Figure 6.3 Movements of Stock Price Index and the RMB Exchange Rate

CPR_t means CPR intervention ($CPR_t > 0$: high CPR intervention [depreciates the yuan], $CPR_t < 0$: low CPR intervention [appreciates the yuan], and $CPR_t = 0$: no intervention) on day t . CB_t is CB intervention ($CB_t = 1$: purchase US dollar [depreciates the yuan], $CB_t = -1$: sell US dollar [appreciates the yuan], and $CB_t = 0$: no intervention). The lean-against-the-wind hypothesis is that purchase intervention (sale intervention) or high CPR intervention (low CPR intervention) by the monetary authorities is intended to depreciate (appreciate) the exchange rate (Sarno and Taylor, 2001). Therefore, in model (6.20), purchase of US dollars by the PBOC should increase returns r_t ; the opposite should hold for sale of US dollars. Both β_0 and ω_0 should be positive, meaning that interventions tend to move the exchange rate in the desired direction. One concept of ‘success’ of interventions discussed in Hillebrand et al. (2009) is the reduction of exchange rate volatility. The relation between the exchange rate volatility and interventions should be negative ($\lambda < 0$). Both types of interventions enter in absolute value.

Following Hoshikawa (2008), Hassan (2009) and Utsunomiya (2013), the frequency of intervention is expected to impact the exchange rate movements and volatility. π_t^{CPR} and π_t^{CB} are variables to test effects of CPR intervention frequency and CB intervention frequency respectively. Because infrequent intervention is considered as a surprise to market agents and should have an effective impact on the exchange rate level, the signs of β_1 and ω_1 are expected to be negative (Hassan, 2009). In addition, because volatility will be small when π_t^{CPR} and π_t^{CB} are large, the coefficients τ_0 and τ_1 in the variance equation are expected to have negative signs.

Each regime in the conditional variance equation includes the asymmetric component given by the term $\varphi\eta_{t-1}^2$ where $\eta_t = \min(0, \mu_t)$. McKenzie (2002), amongst others, proves that the uncertainty of foreign exchange intervention is not symmetric in the presence of positive and negative shocks to exchange rates. This asymmetric component allows us to test whether or not asymmetric exchange rate return volatility is prevalent in both regimes.

Then, because there are two regimes in the first and third sub-samples, we estimate a DTGARCH model as follows:

$$r_t = \begin{cases} c_{10} + \sum_{k=1}^p \theta_{1k} r_{t-k} + \alpha_{10}(i_t - i_t^*) + \alpha_{11} ST_t + (\beta_{10} + \beta_{11} \pi_t) Int_t + \mu_t & \text{if } r_{t-d^*} \leq \gamma \\ c_{20} + \sum_{k=1}^p \theta_{2k} r_{t-k} + \alpha_2(i_t - i_t^*) + \alpha_{21} ST_t + (\beta_{20} + \beta_{21} \pi_t) Int_t + \mu_t & \text{if } r_{t-d^*} > \gamma \end{cases}$$

$$h_t = \begin{cases} \Phi_{10} + \Phi_{11} h_{t-1} + \Phi_{12} \varepsilon_{t-1}^2 + \lambda_{10} |Int_t| + \tau_{10} \pi_t + \varphi_1 \eta_{t-1}^2 & \text{if } r_{t-d^*} \leq \gamma \\ \Phi_{20} + \Phi_{21} h_{t-1} + \Phi_{22} \varepsilon_{t-1}^2 + \lambda_{20} |Int_t| + \tau_{20} \pi_t + \varphi_2 \eta_{t-1}^2 & \text{if } r_{t-d^*} > \gamma \end{cases} \quad (6.25)$$

where $E(\mu_t) = 0$, $\mu_t = \sqrt{h_t} z_t$, and z_t follows a Student's t-distribution with v degrees of freedom. The values for p and γ have been determined in section 6.4.2.

Finally, for the second sub-sample, given the absence of nonlinearities in the RMB exchange rate returns, the linear model is estimated:

$$r_t = c_0 + \sum_{k=1}^p \theta_k r_{t-k} + \alpha_0(i_t - i_t^*) + \alpha_1 ST_t + (\beta_0 + \beta_1 \pi_t) Int_t + \mu_t$$

$$h_t = \Phi_0 + \Phi_1 h_{t-1} + \Phi_2 \varepsilon_{t-1}^2 + \lambda_0 |Int_t| + \tau_0 \pi_t + \varphi \eta_{t-1}^2 \quad (6.26)$$

where $(\mu_t) = 0, \mu_t = \sqrt{h_t}z_t$, and z_t follows a Student's t-distribution with v degrees of freedom. Based on the AIC, $p = 1$.

Table 6.8 Total Sample Result from Three-Regime Threshold Model

Total sample: 2005/07/22-2013/07/22			
	Regime 1	Regime 2	Regime 3
Conditional Mean			
c_0	0.0175 (0.406)	0.0528*** (5.464)	0.0756** (2.032)
θ_1	0.0027 (0.058)	0.0118 (0.407)	-0.0634 (-1.196)
α_0	0.0008* (1.705)	0.0020*** (5.896)	0.0006 (0.599)
α_1	-0.0134 (-0.618)	-0.0305*** (-5.826)	-0.0421** (-2.144)
β_0	8.8693*** (3.683)	3.6414*** (5.560)	1.0864 (0.758)
ω_0	0.0292 (1.531)	0.0177*** (3.101)	0.0628*** (4.643)
β_1	-11.2226*** (-3.040)	-2.9733*** (-2.828)	1.4705 (0.600)
ω_1	-0.0769 (-1.481)	-0.0239* (-1.808)	-0.1363 (-3.657)
Conditional Variance			
Φ_0	0.0024* (1.914)	0.0005*** (7.258)	-0.0005*** (-3.792)
Φ_1	0.3403*** (2.860)	0.3739*** (8.412)	-0.0194 (-0.202)
Φ_2	-0.0206 (-0.272)	0.2286*** (4.916)	0.0290 (0.325)
λ_0	0.1705*** (3.361)	0.0591*** (11.505)	0.1453*** (2.837)
λ_1	0.0009** (2.449)	0.0001*** (4.523)	0.0003 (1.090)
τ_0	-0.0019* (-1.891)	-0.0001*** (-3.491)	0.0002*** (3.383)
τ_1	-0.0033* (-1.680)	-0.0007*** (-6.369)	0.0005 (1.591)
φ	0.0745 (0.750)	0.0368 (0.595)	0.0728 (0.614)
$Q(20)$	32.54	(0.3932)	
$Q^2(20)$	16.374	(0.2641)	
$\ln L$	6114.36		
Observations	2087		

6.5 Empirical Results

In order to illustrate the intervention effects on the Chinese foreign exchange market, we now analyse the empirical evidence unearthed. The three-regime threshold model introduced by Chen et al. (2010), the double threshold GARCH model estimated by Suardi (2008) and Utsunomiya (2013), and the linear GARCH model followed by Hoshikawa (2008) are used to get the empirical evidence for the whole sample and three different sub-samples, respectively.

6.5.1 Results for the Whole Sample Period

Table 6.8 reports the estimated coefficients of model (6.24) on the daily total time period data: 22 July, 2005 to 22 July, 2013. The effects of CPR intervention and CB intervention on the RMB exchange rate movement are captured by coefficients β_0 and ω_0 , respectively. The coefficients β_0 for CPR_t are positive and significant at the 1% level in regime 1 and regime 2, while the coefficients ω_0 are significant at the 1% level in regime 2 and regime 3. These estimated results of β_0 and ω_0 suggest that when the RMB exchange rate appreciates, CPR intervention has effects on the level of the exchange rate, but when the RMB depreciates against the USD, only CB intervention impacts on the exchange rate movement. In addition, both CPR and CB interventions are effective in moving the exchange rate in the desired direction when there is not large depreciation or large appreciation in the RMB currency. The leaning-against-the-wind hypothesis assumes that the purchase intervention (low CPR intervention) can

depreciate the currency and the opposite should hold for sale intervention (high CPR intervention) (Sarno and Taylor, 2001). Thus, β_0 and ω_0 are expected to have positive signs.

Assumed by Hoshikawa (2008) and Utsunomiya (2013), if intervention happens as a surprise, that is the intervention frequency variable is small, it could have a large effect on the exchange rate level. The relation between the intervention frequency and the exchange rate movement should be negative. Referring to results from Table 6.8, the coefficients β_1 for CPR intervention are negative and significant in regimes 1 and 2. The coefficient w_1 for CB intervention is negative and just significant at the week level in regime 2. Therefore, negative signs of significant coefficients β_1 and ω_1 prove the assumption introduced by Hoshikawa (2008) and Utsunomiya (2013).

For the control variables, the coefficients α_0 for interest rate differentials are positive and significant in regimes 1 and 2. The positive signs of interest rate spread support the findings of Gumus (2002) that a higher interest rate differential depreciates the domestic currency. The coefficients α_1 for stock index are negative and significant in regimes 2 and 3. These results of coefficient α_1 support the second hypothesis that if the stock market declines, the currency will depreciate.

Focusing on the conditional variance equation, the results suggest that both of CPR intervention and CB intervention increase the volatility of the daily RMB exchange rate returns. Except the coefficient λ_1 for CB in regime 3, all of coefficients λ_0 are

positive and statistically significant for all specifications. This is consistent with the result obtained by Dominguez (1998), Nagayasu (2004), Hoshikawa (2008) and Utsunomiya (2013)—intervention increases exchange rate volatility. An uncertain or non-credible intervention policy leads to increase volatility (Macedo et al., 2003).

The significance condition of coefficients τ_0 for CPR intervention frequency and τ_1 for CB intervention frequency are negatively significant at regimes 1 and 2. Hoshikawa (2008) and Utsunomiya (2013) find that because high-frequency intervention reduces exchange rate volatility, the coefficients of the intervention frequencies are expected to have negative signs. However, compare to regime 3, the τ_0 for CPR intervention frequency is negatively significant in regime 1. Therefore, we find that high-frequency intervention reduces exchange rate volatility more strongly when the yuan appreciates.

The coefficients φ are non-significant in all regimes, indicating there is no evidence of asymmetric volatility in RMB exchange rate return in these three regimes.

Diagnostics for standardized residuals indicate that correlation between residuals and heteroscedasticity does not exist in the three-regime threshold model. Ljung-Box test statistics indicate that there are no serial correlations in the residuals up to order of 20 ($Q(20) = 32.54$, no significance). In addition, there is no evidence for heteroscedasticity ($Q^2(20) = 16.37$).

Table 6.9 Sub-Sample Results from DTGARCH and Linear GARCH models

	Sub-sample 1: 2005/07/22-2008/07/14		Sub-sample 2:2008/07/15-2010/06/21	Sub-sample 3:2010/06/22-2013/07/22	
	Regime 1	Regime 2		Regime 1	Regime 2
	Conditional Mean				
c_0	0.0353** (2.476)	0.0520 (1.147)	-0.0044 (-0.476)	0.3236 (1.533)	0.0894 (1.449)
θ_1	-0.0294 (-0.745)	0.0106 (0.096)	-0.2094*** (-4.618)	-0.0103 (-0.121)	0.0077 (0.263)
θ_2	-0.0751** (-1.951)	0.0009*** (2.847)	-	-	-
α_0	-0.0002 (-0.264)	0.0009 (0.354)	0.0003 (0.256)	0.0024 (0.587)	0.0008 (0.802)
α_1	-0.0242*** (-3.170)	-0.0345 (-1.432)	0.0020 (0.396)	-0.1693* (-1.695)	-0.0485 (-1.561)
β_0	6.6848** (2.094)	-0.3517 (0.039)	1.1629 (1.245)	0.4354 (0.130)	2.7118** (2.3894)
ω_0	0.0244*** (4.235)	0.0735 (0.836)	0.0087** (1.966)	0.0242 (0.813)	0.0204* (1.733)
β_1	-7.6804* (-1.682)	1.9480 (-0.148)	6.8340** (2.362)	6.0296 (1.064)	-0.1985 (0.093)
ω_1	-0.0326*** (-2.685)	-0.1631 (-0.574)	-0.0334 (-1.193)	-0.0479 (-0.623)	-0.0305 (-1.170)
	Conditional Variance				
ϕ_0	0.0013*** (2.691)	-0.0034 (-0.436)	0.00005*** (6.097)	0.0015 (0.771)	0.0020*** (3.280)
ϕ_1	0.4437*** (43.870)	-0.0911 (-0.530)	0.4921*** (6.842)	0.2683 (0.819)	0.1491* (1.686)
ϕ_2	0.1356** (2.32)	0.1574 (0.636)	0.1988* (1.820)	0.2486 (1.006)	-0.0364 (-0.977)
λ_0	0.0234*** (3.286)	0.1398 (1.488)	0.0410*** (3.016)	0.1711** (2.282)	0.1740*** (5.067)
λ_1	-0.0005*** (-6.921)	-0.0005 (-1.252)	0.00005** (2.476)	-0.0005 (-1.106)	0.0004*** (2.958)
τ_0	-0.0004 (-0.533)	0.0066 (1.357)	0.0029*** (27.648)	-0.0017 (-0.977)	-0.0006 (-1.292)
τ_1	-0.0009*** (-3.502)	0.0102 (0.058)	-0.0059*** (-31.715)	0.0051 (0.172)	-0.0030*** (-3.014)
φ	0.0083 (0.112)	0.3712 (1.079)	-0.1509 (-1.107)	-0.2784 (-1.049)	-0.0029 (-0.977)
$Q(20)$	22.508	(0.433)	21.782 (0.382)	21.373	(0.267)
$Q^2(20)$	14.573	(0.743)	13.369 (0.238)	12.566	(0.480)
$\ln L$	1487.24		1351.48	1328.65	
Observations	891		391	805	

6.5.2. Results for the Sub-Sample Estimation: Before, During and After the Crisis

Before the Financial Crisis

The estimation results for the first sub-sample are presented in Table 6.9. The results of the conditional mean equation of the DTGARCH model for this sub-sample suggest that interventions and intervention frequency can impact the exchange rate movements only when the yuan appreciates. The coefficients of β_0 and ω_0 are positive and significant at 5% level and 1% level respectively in regime 1. Thus, both CPR intervention and CB intervention are successfully used for the leaning-against-the-wind policy before the 2008 financial crisis. With regard to intervention frequency, the significant coefficients β_1 and ω_1 appear only in regime 1. The negative signs of coefficients β_1 and ω_1 prove that the low-frequency interventions have large effects on the exchange rate level, similar to the findings for the whole time period. Among the control variables, only stock price has negative and significant relation with the exchange rate movement in regime 1. This result also supports the second hypothesis, that the depreciation of domestic currency follows the decline of the stock market.

Turning to the conditional variance, again, interventions and frequency influence the volatility of exchange rate returns only when the yuan appreciates. The coefficients λ_0 and λ_1 are significant at 1% level in regime 1, but own opposite signs: the coefficient λ_0 is positive (0.023) and the coefficient λ_1 is negative (-0.0005). Based on these results, we find that CPR intervention increases the volatility of the daily RMB exchange rate returns, while CB intervention can reduce the volatility when

there is appreciation of RMB exchange rate before the financial crisis. Considering the intervention frequency, only the coefficient τ_1 is negative and statistically significant in regime 1. This indicates that in sub-sample 1, the CB intervention frequency can reduce the exchange rate volatility when the yuan appreciates.

During the Financial Crisis

Because according to Hansen's model-based bootstrap procedure there is only one regime in sub-sample 2, the effects of interventions on the exchange rate movement and volatility during the 2008 financial crisis are tested by a linear GARCH model. The coefficient in the mean equation (6.26), ω_0 , is positive and significant at the 5% level in sub-sample 2. This suggests that only the CB intervention has an effect on the exchange rate level during the financial crisis. Referring to the results of the variance equation, the CPR and CB interventions increase the volatility of RMB exchange rate returns. Both the coefficients λ_0 and λ_1 are positive and statistically significant in sub-sample 2. Then, because the coefficient τ_1 is negative and significant at the 1% level, we find that high-frequency CB intervention can reduce the exchange rate volatility. We need to pay particular attention to the signs of coefficients β_1 and τ_0 . In the hypotheses, because the volatility of the exchange rate decreases with high frequency intervention and low frequency intervention has a large effect on the exchange rate level, the signs of coefficients β_1 and τ_0 are expected to be negative. However, the signs of both β_1 and τ_0 are positive (6.83 and 0.003). These results, which suggest that high frequency CPR intervention has large effects on the RMB exchange rate movement and increases the RMB exchange rate volatility, are contrary to the hypotheses. The pegging exchange rate regime applied

during the financial crisis meant that only high frequency intervention could affect the movement of RMB exchange rate level and volatility.

After the Financial Crisis

According to the results of the DTGARCH model in sub-sample 3, the CB intervention and CPR intervention have effects on the exchange rate movement only when the yuan depreciates. The coefficients β_0 and ω_0 are positive and significant in regime 2. Based on these results, we find that the CB and CPR interventions are successfully used for the leaning-against-the-wind policy after the financial crisis. The results for the control variables in sub-sample 3 are similar to those for sub-sample 1. That is, only stock price has negative and significant relation with the exchange rate movement when the yuan appreciates. This result supports the second hypothesis, that the depreciation of domestic currency follows the decline of the stock market.

The coefficients λ_0 in the variance equation are positive and significant in both regime 1 and regime 2. Only the coefficient λ_1 is significant at 1 % level in regime 2. These results prove that interventions increase the RMB exchange rate volatility. Considering the intervention frequency, only the coefficient τ_1 is negative and statistically significant in regime 2. This indicates that in sub-sample 3, the CB intervention frequency can reduce the exchange rate volatility when the yuan depreciates.

Overall, the empirical evidence suggests that before the financial crisis interventions in the foreign exchange market were more effective when the exchange rate was appreciating, and that after the financial crisis interventions have large effects on the foreign exchange market when the exchange rate depreciates. It can be concluded that between July 2005 and July 2008 the objective of the monetary authority was to offset the effects of exchange rate appreciations through interventions. In contrast, between June 2010 and July 2013 the authority used intervention in order to influence the exchange rate movement and volatility when the exchange rate was depreciating. This indicates that the objectives of intervention are different before and after the financial crisis.

The empirical evidence for the asymmetric component proves that asymmetric volatility in the RMB exchange rate return does not exist in these three sub-samples. The coefficients φ are non-significant in all sub-samples.

The results for coefficients β_0 , ω_0 , β_1 , ω_1 , λ_0 , λ_1 , τ_0 , and τ_1 follow the same pattern in the whole sample. The coefficients β_0 and β_1 are larger than ω_0 and ω_1 (6.68 versus 0.02, 7.68 versus 0.03 and so on) in all the mean equations. In addition, for all variance equations, the coefficients λ_0 are larger than the λ_1 (0.023 versus 0.0005 and so on). However, the magnitudes of coefficients τ_0 are smaller than the numbers of τ_1 (0.0004 and 0.0009). These results suggest that CPR intervention and CPR intervention frequency have stronger effects on the RMB exchange rate level than do CB intervention and frequency, and that the effects of CPR intervention on the exchange rate volatility are larger than the effects of CB intervention, but the

effects of CPR intervention frequency are less than those of CB intervention frequency.

The results from the diagnostics for standardized residuals prove that there is no relation between residuals and no heteroscedasticity for all specifications. All of $Q(20)$ and $Q^2(20)$ are non-significant in all models.

6.6 Conclusions

This chapter has attempted to discover the effects of China's intervention on the foreign exchange market. Despite the growing awareness in international policy circles and academia that intervention is a central feature of China's exchange rate policy, there is a lack of research on the relation between China's foreign exchange intervention and its consequences. Through its consideration of CPR intervention and CB intervention in China, which may be the most watched emerging market in the field of foreign exchange rate policy, this research contributes to the previous literature on central bank intervention. This chapter uses the data of CPR intervention and CB intervention from Chapters 4 and 5, and calculates the CPR and CB intervention frequencies to analyse the effects of China's intervention and frequency on the foreign exchange market using threshold GARCH approaches. We first use Hansen's model-based bootstrap procedure to determine the number of regimes in the whole sample and three sub-samples. Then, Tsay's arranged autoregression method is used to get the order of the lag structure (p) for the AP model and the optimal delay parameter, and Chan's test is applied to obtain the

threshold value and the RSS. Because there are three regimes in the whole time period, two regimes in the first and third sub-samples, and one in the second sub-sample, we estimate the triple-threshold GARCH model, double threshold GARCH model, and linear GARCH model to test whether or not China's intervention and intervention frequency can move the USD/CNY exchange rate in the desired direction and reduce the exchange rate volatility in the whole sample and three sub-samples.

Using the triple-threshold GARCH model, we get evidence of the effects of China's intervention and intervention frequency on the foreign exchange market in the whole sample (22 July, 2005 to 22 July, 2013). For the exchange rate level, results show that when the RMB exchange rate appreciates, CPR intervention has effects on the level of the exchange rate, but when the RMB depreciates against the USD, only CB intervention impacts on the exchange rate movements. In addition, both CPR and CB interventions can effectively move the exchange rate in the desired direction when there is neither large depreciation nor large appreciation in the RMB currency. Furthermore, because all the coefficients β_0 and ω_0 have positive signs in the three regimes, we find that with regard to CB and CPR interventions, the PBOC has been successful in using them for the leaning-against-the-wind policy. Then, comparing the results of CPR intervention frequency and CB intervention frequency, we find that the effects of low-frequency CPR intervention on the exchange rate level are stronger than the effects of low-frequency CB intervention not only in the yuan appreciation period, but also in the period without large appreciation or large depreciation in the RMB currency. For the exchange rate volatility, the results suggest that both CPR intervention and CB intervention increase the volatility of the

daily RMB exchange rate returns. Comparing the coefficients of CPR and CB intervention frequency variables between regime 1 and regime 3, we find that high-frequency intervention reduces exchange rate volatility more strongly when the yuan appreciates.

With regard to the effects of China's intervention on the foreign exchange market before, during and after the 2008 financial crisis, this chapter applies linear and double threshold GARCH models to analyse the time-varying effects of China's intervention. The empirical evidence suggests that before the financial crisis interventions were more effective when the exchange rate was appreciating, and that after the crisis interventions have large effects on the foreign exchange market when the exchange rate depreciates. It can be concluded that between July 2005 and July 2008 the objective of the monetary authority was to use interventions to offset the effects of exchange rate appreciation. In contrast, from June 2010 to July 2013 the authority used interventions in order to influence the exchange rate movement and volatility when the exchange rate depreciated. This indicates that the objectives of intervention are different before and after the financial crisis. According to the results for the period during the financial crisis, only CB intervention could impact the exchange rate return, and only high-frequency CB intervention had the desired effects on volatility. Although high-frequency CPR intervention also had effects on the RMB exchange rate movements and volatility, the signs of CPR intervention frequency variables are opposite to the hypotheses, which assume negative signs of frequency variables. The reason may be that, during the financial crisis, only high frequency intervention could affect the foreign exchange market.

This research also sheds light on the relation between interest rate spreads and stock price index and the RMB exchange rate movement. Interest rate differentials are positively related with the RMB exchange rate movement, indicating that a higher interest rate differential depreciates the domestic currency. The negative relation between stock price index and RMB exchange rate movement reflects the fact that if the stock market declines, the currency will depreciate. Based on the numbers of intervention and intervention frequency coefficients, we suggest that CPR intervention and CPR intervention frequency have stronger effects on the RMB exchange rate level than do CB intervention and frequency, and that the effects of CPR intervention on the exchange rate volatility are greater than the effects of CB intervention, but the effects of CPR intervention frequency are less than those of CB intervention frequency.

Chapter 7

Oral Intervention in China: Efficacy of Chinese Exchange Rate Communications

7.1 Introduction

Traditionally, monetary authorities have intervened directly in foreign exchange markets, impacting exchange rate levels and their fluctuations by actually trading currencies. In recent years, however, actual intervention has been supplemented or supplanted by oral intervention, i.e., official communications via policy announcements or other means such as informal meetings with market participants intended to mitigate exchange rate trends by influencing market expectations (Fratzscher, 2006, 2008a, 2008b; Beine et al., 2009; Sakata and Takeda, 2013). For major economies like the US and EU member nations, there has been almost no direct market intervention by the authorities since the mid-1990s; however, the frequency of oral interventions has increased.

In China, the monetary authorities engage in both actual and oral interventions. Although this intervention is not publicly acknowledged, we do know when the People's Bank of China (PBOC) makes statements directly to the foreign exchange market or talks to the state-owned banks. In recent years, the PBOC has announced that it will gradually reduce direct or 'regular' interventions in the Chinese exchange

market. However, given the PBOC's long history of extensive intervention, this change is likely to be one of form rather than substance.

China has been internationally noted for the extent and sophistication of its foreign exchange interventions. As stated in previous chapters, generally, we can identify three major forms of Chinese intervention: (1) Direct sales or purchases of foreign currencies by the PBOC in the marketplace; (2) Setting and adjusting of the official central parity rate and the range around which the daily trading prices are allowed to fluctuate; and (3) PBOC oral intervention in the form of policy briefing, moral persuasion, formal and informal meetings, and telephone conversations. The first two are regularly operated by the PBOC, and the central bank's indication of a gradual reduction in regular interventions is likely to mean a move towards engaging more in oral intervention.

Although many researchers have studied China's exchange rate policy and have recognized intervention as a central feature of that policy, to date there has been very little research attention directed toward China's oral intervention. The first contribution is to fill the gap in the foreign exchange intervention literature by considering the Chinese case.

The existing literature on oral intervention as a policy tool has found mixed results. Recent studies have shown some progress in mitigating the problems in previous research. For example, intervention studies have applied the event study methodology, which is considered to be better at capturing the clustered property of

interventions compared to time-series analysis (Fratzcher 2008a; Gnabo and Teiletche, 2009).

This chapter follows the event study approach to explore China's oral intervention in the foreign exchange market in order to better our understanding of China's exchange rate. We consider both domestic and international aspects of China's exchange rate communication, including China's response to international calls for exchange rate adjustment, which is the second contribution, particularly those from the USA.

We analyse the effects of oral intervention on the US dollar/Chinese yuan (USD/CNY) rate from 22 July, 2005 to 22 July, 2013. Four event window lengths - of 2, 5, 10 and 15 days - are deployed to check when the effects of oral intervention occur. Four dimensions - event, direction, reversal and smoothing - are investigated to test for the impacts of the events. We also employ more extensive tests in the empirical investigation. The event study approach that is commonly used in other similar research is based almost exclusively on the sign tests. In this research we extend the literature by employing the rank tests along with the sign tests, to check to what extent the communications may have the desired effects. The third contribution is to compare the results of parametric and nonparametric tests, as the nonparametric tests may yield additional insights in the context of the event studies.

We find that exchange rate communications can help the Chinese central bank move RMB exchange rate levels in the desired direction. Based on the whole sample results, although against the event criterion exchange rate communications are not

successful, in the reversal dimension all the event window lengths under examination are significant. Finally, the longer the event window length is, the more significant the effects are in the four dimensions. We also test the effects of the international aspects of China's exchange rate communications, particularly in the case of the US calling for appreciation of the RMB exchange rate. As the events are significant in all dimensions, the results suggest that such calls can influence movements of the Chinese exchange rate, and hence by and large the Chinese authorities are responsive to American pressure for RMB appreciation. Finally, using the range-based variance model to get volatility, we find confirmative evidence of the effect of successive exchange rate communications on calming the exchange rate movement in terms of excess volatility.

The rest of this chapter is organized as follows. Section 7.2 comprises a review of the literature on oral intervention. Section 7.3 introduces the forms of intervention in China with a focus on China's oral intervention. Section 7.4 explains the event study methodology; it defines the events, event windows and criteria, and describes the parametric and nonparametric tests. Section 7.5 discusses the estimation results. Section 7.6 offers concluding remarks.

7.2 Related Literature

In recent decades, exchange rate communication has become an increasingly important policy tool for monetary authorities (Fratzcher, 2006). Using reports issued by the newswire service Reuters News, Fratzcher (2006) analyses exchange

rate communication on the basis of two sets of search criteria. These are used to extract all statements in which policy makers express a view about the domestic exchange rate. The search terms are the phrase ‘exchange rate’ or the name of the exchange rate, such as the US dollar for the United States, and the title or name of relevant policy makers. Then, Fratzscher (2006) classifies the contents of the statements according to whether they support a stronger domestic currency or a weaker one, or are neutral:

$$IO_t = \begin{cases} +1 & \text{if 'strengthening' oral statement;} \\ 0 & \text{if 'ambiguous' oral statement;} \\ -1 & \text{if 'weakening' oral statement;} \end{cases} \quad (7.1)$$

Using the above classification process, Fratzscher (2006) identifies exchange rate communication in the Group of Three (G3), comprising the USA, Japan and the euro area, from 1990 to 2003. The findings show that from the mid-1990s the United States and the euro area had practically abandoned the use of actual purchase and sale in FX markets, and shifted to almost exclusive use of communication to affect exchange rate developments. The Japanese authorities, however, had intensified both actual intervention and exchange rate communication. The empirical results based on an EGARCH framework indicate that communication not only exhibits a significant contemporaneous effect on exchange rates, but also moves forward exchange rates in the desired direction up to a horizon of 6 months. Moreover, communication is found to reduce exchange rate volatility and uncertainty, whereas actual interventions tend to have the opposite effect. Overall, communication tends to be a fairly effective policy tool over the medium term.

In a subsequent study, Fratzscher (2008) investigates the channels through which communication works. Using the same data and search classification process as in his 2006 research, Fratzscher (2008) employs a standard asset-pricing framework. The research provides two key findings: first, G3 communication policies have constituted an effective policy tool in influencing exchange rates in the desired direction; second, communication has been effective independently of the stance and direction of the monetary policy and the occurrence of actual interventions. Meanwhile, the effects of communication are strongly related to the degree of uncertainty and the positioning of participants in FX markets. Taken together, the results provide support for micro-based approaches to exchange rate modelling and are consistent with the argument that oral and actual interventions function through a coordination channel rather than a signalling channel.

One key question for Fratzscher (2008) is whether communication is successful in inducing a long-term effect on exchange rates. Still using the same data as in his 2006 research, Fratzscher (2008) employs an event study methodology based on four criteria - 'event', 'direction', 'reversal', and 'smoothing' - and nonparametric sign tests. The empirical findings for the success of interventions based on these criteria provide strong evidence for the medium- to long-term effectiveness of both oral interventions and actual interventions by G3 authorities since 1990. Then, Fratzscher (2008) attempts to gauge the channels through which these two types of intervention function. He tests hypotheses for the channels: if the portfolio balance channel is dominant, one would expect that oral interventions should have little or no effect on exchange rates; if the signalling channel is working, a close relationship

between monetary policy and the effectiveness of interventions would be expected; if the coordination channel is relevant, interventions may be most effective in times of large market uncertainty or when exchange rates strongly deviate from fundamentals (Taylor, 2004).

In order to test the coordination channel, Fratzscher (2008) applies a formal test using odds ratios in a logit-model framework. The findings show that both oral and actual interventions are effective under large market uncertainty and when exchange rates deviate substantially from fundamentals. Fratzscher (2008) also finds that the success of communication and actual interventions is largely unrelated to monetary policy, thus suggesting that interventions function primarily through a coordination channel.

Using Dow Jones and Reuters press reports to identify oral interventions during 1989-2003 for the USD/DEM (the EUR/USD after 1999), and during 1991-2003 for the YEN/USD, Beine et al. (2009) assess how communication influences exchange rate levels and exchange rate volatility. They consider two types of communication: ex post communication includes all the official statements detected by market participants that are issued after direct interventions, while ex ante communication comprises statements issued at G7 meetings or potential future interventions issued by monetary authorities. The results indicate that oral intervention has effects on both exchange rate level and exchange rate volatility. Moreover, statements by monetary authorities on exchange rate policy can be a valuable complementary tool to actual exchange rate operations. The authors also conduct robustness checks for a range of factors: change in intervention regime, size of the intervention, the

coordination channel, official statements as separate policy instruments, and the distinction between announced and unannounced interventions.

Sakata and Takeda (2013) attempt to complement Fratzscher's (2008) study, which examines only the effect of announcements made by main monetary authorities and does not exclude the possibility that other speakers may also influence the market. Using Reuters Japanese News, Sakata and Takeda (2013) collect statements by Japanese monetary authorities from 1 January 1995 to 31 May 2011. Then, following Fratzscher (2008), they regard oral intervention as an event, and define the success or failure of oral intervention by measuring whether it meets certain criteria. They use 'direction' as the criterion to analyse whether oral interventions can influence the exchange rate as the monetary authorities' hope. In their study, Sakata and Takeda (2013) construct dummy variables based on 14 points (direction, specific rate, IA-announcement, suggestion, non-comment, watching, attitude, coordination, vice-minister, minister, MoF-member, BoJ, Japanese, International), and apply logit analysis to investigate what forms of oral intervention are most effective. Results from this event study suggest that the market only responds to the statements made by main monetary authorities. In addition, Sakata and Takeda (2013) find that market participants give high credence to announcements that strike a decidedly positive or negative tone about the current exchange rate. Moreover, their results indicate that the effects of oral interventions depend on the speaker and the content; consequently, they provide policy implications.

Using Japanese data from April 1991 to September 2004, Bernal and Gnabo (2009) classify three types of intervention: actual intervention, oral intervention and

confirmed intervention. Confirmed intervention is an actual intervention accompanied by an announcement either confirming its occurrence or clarifying its purpose. Bernal and Gnabo (2009) collect the oral and confirmed intervention information from the Factiva online database. They estimate an ordered probit model to test determinants of different types of interventions, and then use an event study approach to examine the effectiveness of the interventions. Their results indicate that the Japanese authorities tend to adopt stronger measures when the behaviour of the exchange rate becomes more unfavourable. This suggests that words and deeds are coordinated only in extreme cases. Overall, interventions are found to be moderately successful in correcting undesirable exchange rate developments, especially volatility of the exchange rate movements.

Fratzscher (2004) discusses three elements of foreign exchange interventions: exchange rate developments, monetary policy and the coordination of interventions. First, with regard to exchange rate developments, intervention focuses on arriving at a particular exchange rate level, decreasing deviations of the exchange rate from the desired level, or reducing volatility. Second, through the signalling channel, intervention seems closely associated with monetary policy. Third, in the international arena, monetary authorities have frequently coordinated their interventions across countries to increase the effectiveness on exchange rates (Bonser-Neal and Tanner, 1996; Beine et al., 2002). Fratzscher (2004) conducts a logit analysis to test these three characteristics of actual and oral interventions in the Japanese context. The results show that both actual and oral interventions follow a leaning-against-the-wind pattern, and are more frequent when exchange rate deviation and volatility are high. In addition, both actual and oral interventions are

mostly consistent with and supportive of monetary policy changes. Furthermore, they are coordinated domestically and internationally.

The literature on China's intervention has not covered the oral type of intervention; nor has it used an event study approach. This chapter aims to fill that critical void.

7.3 Measures of Oral Intervention

Differing from the US, Japan and other mature economies, China operates foreign exchange intervention according to its own unique fashion. The Chinese monetary authorities intervene in the foreign exchange market secretly and the intervention takes a variety of forms. Specifically, quantity intervention takes place via purchase or sale of foreign currencies, price intervention is accomplished via setting the central parity rate for market trading and its allowed fluctuation band, while the authorities also engage in oral intervention through issuing government statements or other means of communication.

In this chapter, we focus on the oral intervention, whereby in order to influence the RMB exchange rate against the dollar, the monetary authorities communicate with the foreign exchange market.

In China's foreign exchange market, oral intervention may be in the form of exchange rate communications by the domestic monetary authorities, but it may also

have an international dimension when the intervention takes place as a result of outside pressure, such as US calls for appreciation of the RMB.

With regard to domestic communication, because the purpose of this chapter is to measure the extent to which exchange rate communication might affect the foreign exchange market in the intended way, we choose to focus on statements by the relevant Chinese monetary authorities, including the PBOC, Ministry of Finance and State Administration of Foreign Exchange (SAFE), and exchange rate speeches by Chinese political and economic leaders such as China's President, Premier, and the PBOC governor. With regard to the exchange rate pressure coming from outside China, which is often calling for appreciation of the Chinese currency, we look at statements made during US-China presidential visits and Strategic and Economic Dialogue, and official statements on exchange rates by the US President, Secretary of the Treasury and senators.

To collect the data on domestic and foreign exchange rate communications we extract headline statements and speeches from newswire service Reuters News, as this is the most likely source of information for market participants (Fratzscher, 2006 and 2008; Beine et al., 2009; Sakata and Takeda, 2013). Because this chapter intends to analyse the market reaction to communication that actually becomes available to market participants, it is important to use a news provider with a good professional reputation for the quality of its services. One advantage of using the newswire service is that statements and official speeches are interpreted by experienced professionals.

Reuters US News is used for data on outside appreciation pressure, and Reuters Chinese News for information on domestic communication. In most cases, media reports from such sources are published within minutes of a policymaker's statement or speech, which allows us to conduct the empirical analysis using the data at daily frequency. For news about developments regarding China's foreign exchange market, we additionally use information from the official websites of the PBOC and SAFE.²⁰ Reports from these sources can be regarded as information released by the Chinese monetary authorities. In addition, we use the newswire service of China.org.cn²¹ as the official source of information from China's National People's Congress (NPC) and the Chinese People's Political Consultative Conference (CPPCC).

In seeking information about outside appreciation pressure we employ two search criteria: The first comprises the phrase 'exchange rate' or the name of the currency - renminbi (RMB) or the Chinese yuan for the People's Republic of China - and the title or name of the US President, Treasury Secretary or senators. As shown in Table 7.1, during the sample period there was a change of US President, so we use both Bush and Obama as search terms, and there were four US Treasury Secretaries, so we use the names Snow, Paulson, Geithner and Lew in the search. Based on the first criterion, we discover indications of calls from the American side regarding the RMB exchange rate. The second criterion relates to the reports, news briefings or statements regarding high level US-China bilateral meetings. This criterion

²⁰ The People's Bank of China (PBOC) website is <http://www.pbc.gov.cn/>, last accessed on 18 March 2015.

The State Administration of Foreign Exchange (SAFE) website is <http://www.safe.gov.cn/>, last accessed on 18 March 2015.

²¹ China.org.cn website is <http://www.china.org.cn/>, last accessed on 18 March 2015.

comprises the name of the exchange rate, along with the name of the bilateral meeting, such as presidential visits to and from the USA and the US-China Strategic and Economic Dialogue, which has taken place once every year since 2009.

Table 7.1 Names and Periods of Tenure for US Presidents and Treasury Secretaries

US President				
Name:	George W. Bush		Barack Obama	
Time:	Before 20/01/2009		After 21/01/2009	
US Treasury Secretary				
Name:	John Snow	Henry Paulson	Timothy Geithner	Jack Lew
Time:	Before 30/06/2006	10/07/2006— 20/01/2009	20/01/2009— 25/01/2013	After 28/02/2013

For domestic communication, we choose Reuters Chinese News, the PBOC and SAFE websites, and China.org.cn as sources. As with Reuters US News, we use two search criteria for Reuters Chinese News. The first comprises the name of the Chinese exchange rate and the name of the Chinese President, Premier, or PBOC governor (see Table 7.2). The main purpose is to find speeches on the RMB exchange rate made by relevant authorities in China. The second criterion comprises the name of the exchange rate along with a phrase connoting a major economic or financial event in China, such as ‘National Financial Work Conference’, or ‘Central Economic Work Conference’, which issue statements about the Chinese exchange rate policy. Then, we use the PBOC and SAFE websites as sources for the China Monetary Policy Report and the Annual Report of the State Administration of Foreign Exchange, respectively. These documents report the evolution of China’s exchange rate policy in a particular year and indicate official intentions for the future development of the policy. Finally, we use the newswire service China.org.cn to collect NPC and CPPCC statements relevant to the Chinese foreign exchange market.

Table 7.2 Names and Periods of Tenure for Chinese President, Premier, and Governor of the PBOC

	Chinese President		Premier	Governor of the PBOC	
Name	Hu Jintao	Xi Jinping	Wen Jiabao	Li Keqiang	Zhou Xiaochuan
Tenure	Before 14/03/2013	After 14/03/2013	Before 15/03/2013	After 15/03/2013	22/07/2005-22/07/2013

Then, in order to provide a systematic classification of the meaning of statements and official speeches, we use the content analysis technique to extract relevant information (Holsti, 1969; Kassirjian, 1977). Given the high research interest in the extent to which communication of the views of domestic or US governments about the Chinese currency would affect the RMB exchange rate, we have a classification of the media of the communication as follows:

$$IO_t = \begin{cases} 5 & US \text{ speech;} \\ 4 & US - China \text{ meeting;} \\ 3 & domestic \text{ meeting;} \\ 2 & domestic \text{ speech;} \\ 1 & domestic \text{ report.} \end{cases} \quad (7.2)$$

where IO_t is the oral communication at time t . There are five channels through which oral intervention may take place. Domestic oral intervention occurs when a statement or speech is issued by the relevant authorities in China, usually at the PBOC or SAFE. Speeches by certain domestic officials, such as China's President, Premier or Central Bank Governor, may also constitute intervention, since they are in a position to change the formulation of the Chinese exchange rate policy. Their

speeches may send messages regarding their judgement on the current status of the RMB exchange rate or about possible changes they intend to make to the RMB exchange rate in the future. Domestic meeting intervention occurs when the content of meetings, such as those of the NPC or CPPCC, and the two central work conferences specified above, concerns the exchange rate. When statements issued during US-China presidential visits and Strategic and Economic Dialogue call for appreciation of the RMB exchange rate, this is defined as US-China meeting intervention. Finally, when the US speaks to China seeking appreciation of the yuan we term this US speech intervention, as China may respond to the call by changing the RMB exchange rate, albeit after some delay. While all US-China meetings and US speech interventions are concerned only with appreciating the RMB exchange rate, the other oral intervention types may have the tone of either appreciation or depreciation (± 1).

For example, according to media reports on 05/04/2006, before the US visit by the then Chinese President Hu Jintao, the then American Treasury Secretary John Snow claimed that, while appreciation of the Chinese yuan could not be achieved immediately, the RMB should increase in that year. In another example, on 28/06/2010, President Obama expressed the hope that the Chinese yuan could appreciate more quickly. According to our classification, these two dates can be categorized as types 5 and 4 of oral intervention, respectively.

On 06/10/2006, the governor of the PBOC, Zhou Xiaochuan, indicated opposition to RMB appreciation, stating the necessity to keep the RMB stable. Therefore, we mark that date as type 2 oral intervention. On 14/11/2006, the PBOC's Monetary

Policy Report stated that the flexibility of the RMB exchange rate regime was increasing, and reform of the exchange rate regime was well underway. These developments would increase public anticipation that appreciation would be more likely to occur. Thus, we mark that date as type 1 of oral intervention.

Table 7.3 shows the occurrence of the five types of oral intervention since 2005. There are some prominent features. Most importantly, we can identify distinct regimes of oral intervention over time. For instance, oral intervention happened less under the pegged exchange rate system: among the whole sample, the sub-period 15/07/2008-22/06/2010 saw the lowest number of oral interventions. This is because during that period central parity intervention was the main tool used by the central bank to influence the RMB exchange rate. With regard to types of domestic oral interventions and oral communications from the US, we find that the largest numbers are for domestic and US speeches. This means that the main form of oral intervention is simply talking to the foreign exchange market.

Table 7.3 Number of Exchange Rate Communications, 2005-2013

	Total	Domestic report	Domestic speech
2005/07/22-	362	55	138
2013/07/22	(91&-271)	(18&-37)	(92&-46)
2005/07/22-	150	20	51
2008/07/14	(33&-117)	(4&-16)	(27&-14)
2008/07/15-	84	14	37
2010/06/22	(47&-37)	(11&-3)	(31&-6)
2010/06/23-	128	21	50
2013/07/22	(40&-88)	(3&-18)	(34&-16)

	Domestic meeting	US-China meeting	US speech
2005/07/22-	18	22	129
2013/07/22	(10&-8)	(-22)	(-129)
2005/07/22-	4	17	58
2008/07/14	(2&-2)	(-17)	(-58)
2008/07/15-	5	3	25
2010/06/22	(5)	(-3)	(-25)
2010/06/23-	9	2	46
2013/07/22	(3&-6)	(-2)	(-46)

Notes: Numbers in parentheses refer to the oral interventions for appreciation (with a negative sign -) and depreciation (with a positive sign +).

7.4 The Event Study Methodology

7.4.1 History of Event Study Methodology

Fama et al. (1969) were among the first to use the event study approach to finance research. Subsequently, Brown and Warner (1980 and 1985) elaborated the basics of the methodology (Binder, 1998). The approach starts with the identification of the event. Then, pre-event and post-event periods can be defined (Gnabo and Teiletche, 2009). Based on Fatum and Hutchinson (2006) and Morel and Teiletche (2008), the approach deployed in the foreign exchange field uses Equation (7.3) below to test

two null hypotheses regarding changes in the exchange rate returns in the pre- and post-event periods:

$$H_0^1: E(\Delta M_i^{post}) = 0$$

$$H_0^2: E(\Delta M_i^{post} - \Delta M_i^{pre}) = 0 \quad (7.3)$$

These two hypotheses were tested by Fatum and Hutchinson (2006) for exchange rate returns. ΔM_i^{post} and ΔM_i^{pre} are changes in the exchange rate movement of the pre- and post-event periods, respectively. The first null hypothesis (H_0^1) is used to test whether intervention events cause significant changes in exchange rate movements in the post-event period, and this corresponds to the direction test. The second null hypothesis (H_0^2) is used to determine whether pre-event changes in the exchange rate are significantly different from post-event changes, and it corresponds to the reversal test and smoothing test.

Event Studies in Advanced Countries

An event study framework is better suited to the study of sporadic and intense periods of official intervention than are standard time-series studies (Fatum and Hutchison, 2003). Fatum and Hutchison (2003) use the daily Bundesbank intervention and Fed intervention variables during the period from 1 September, 1985 to 31 December, 1995. Following Frankel (1994) and Humpage (1999), Fatum and Hutchison (2003) take the direction and smoothing criteria as the measure of

success, and introduce a new criterion, ‘reversal’. Using the nonparametric sign test and matched-sample test, they find strong evidence that sterilized intervention systemically affects the exchange rate in the short run. This means sterilized intervention may play a role in moving the exchange rate. The result is robust to changes in event window definitions over the short run and to controlling for central bank interest rate changes during the event. However, because of the absence of more fundamental policy actions, their results should not be interpreted as a rationale for the longer-term management of exchange rates.

Payne and Vitale (2003) study the effects of Swiss National Bank (SNB) intervention operations using tick-by-tick transaction data between 1986 and 1995. The main contribution of their study is to extend the preliminary analysis of Fischer and Zurlinden (1999) by matching these data with indicative intra-day exchange rate quotes and newswire reports of central bank activity. Using an event study approach, Fischer and Zurlinden (1999) exactly quantified the effects of single intervention operations on the USD/CHF rate at a 15-minute sampling frequency. Their study focuses on the signalling hypothesis, which suggests that intervention operations are used by monetary authorities to convey information to FX markets and hence alter market expectations and exchange rates. Therefore, if central bank operations are informative, signed intervention should have a significant and permanent effect on the value of currencies. Fischer and Zurlinden’s (1999) analysis yields four important findings. First, SNB intervention operations have strong and persistent short-run effects on the USD/CHF. Second, SNB interventions are more effective in conditioning exchange rates when they are coordinated with other central banks. Third, interventions that are with-the-trend have stronger exchange rate impacts.

Finally, the exchange rate can move in the direction of the intervention in the minutes before the actual intervention takes place.

Pierdzioch and Stadtmann (2003) use the event study methodology to analyse the effects of interventions conducted by the Swiss National Bank (SNB) during the period from 1986 through 1995. Like Fatum and Hutchison (2003), Pierdzioch and Stadtmann (2003) define the direction, smoothing and reversal criteria, and apply the nonparametric sign test and matched-sample test. They find some evidence that interventions by the SNB had an impact on exchange rate dynamics. However, the significance of this effect depends on the direction of intervention. In general, their evidence suggests that the SNB interventions to strengthen the Swiss franc were more effective than its interventions to weaken the Swiss franc. In addition, the results of the tests for the effects of the SNB interventions depend upon the length of the pre- and post-event windows analysed.

Using published official daily data on the Bank of Japan's intervention during the period from 1 April, 1991 to 31 December, 2000, Fatum and Hutchison (2006) apply an event study methodology to investigate the effects of that intervention. They use the direction, smoothing and reversal criteria to examine the effects of the intervention episode, and employ two statistical tests: nonparametric sign test and matched-sample test. The nonparametric sign test verifies whether there is a change in direction or reversal of the exchange rate following an intervention event. The matched-sample test, which is identified with the smoothing criterion, verifies whether there is a significant shift in the exchange rate change between the pre- and post-event periods. Pre- and post-event window lengths of 2, 5, 10 and 15 days are

applied. From the results of the nonparametric sign test and matched-sample test, Fatum and Hutchison (2006) find strong evidence that sterilized intervention systemically affects the exchange rate in the short run (less than one month). This result holds even when intervention is associated with (simultaneous) interest rate changes, whether or not intervention is ‘secret’, and against other robustness checks, such as controlling for endogeneity (when the central bank intervenes for multiple days during a single event).

Using an event study approach to test high-frequency (5-minute) euro-dollar exchange rates from 4 January 1999 to 17 May 2002, Jansen and Haan (2007) examine the effects of oral intervention. Focusing on direction, smoothing and volatility, they find that the effects of oral interventions are small and short-lived. Whether or not the verbal intervention is captured in the news report headline is the most important determinant of the effects. Oral interventions which coincide with the release of macroeconomic data are less effective in changing the direction of the exchange rate, but do lead to lower exchange rate volatility. There is no difference between the effects of comments by European Central Bank Executive Board members and those of presidents of national central banks.

Fatum (2008) uses an event study methodology to analyse the effects of official, daily Bank of Canada intervention in the CAD/USD exchange rate over the 1995-1998 period. Like Fatum and Hutchison (2006), Fatum (2008) applies the nonparametric sign test and matched sample test to study the main dimensions of the effects, namely direction, smoothing, and volatility. He finds some evidence that during the period examined intervention was systematically associated with both a

change in the direction and a smoothing of the exchange rate. This means that daily Bank of Canada intervention was effective for both the direction and smoothing criteria. However, the analysis does not find any significant effects of intervention in terms of reducing volatility of the CAD/USD exchange rate.

Fatum (2008) also takes into account the issue of currency co-movements. According to Eun and Lai (2004), the observed exchange rate movements might be driven by major currency factors. Therefore, Fatum (2008) uses the 'filtered' exchange rate to check for currency co-movements. The filtered exchange rate is calculated as the difference between the % change in the 'raw' CAD/USD rate and an equally weighted average of the % change in the GBP/USD, DEM/USD and JPY/USD exchange rates. Fatum (2008) shows that the effects of intervention are weakened when the model is adjusted to capture the general currency co-movements against the USD.

Using Japanese data over the period from 1992 to 2004 and an event study approach, Gnabo and Teiletche (2009) estimate the effect of different strategies on the USD/JPY exchange-rate risk-neutral density. Like Fratzscher (2004, 2006 and 2008), they find that communication policy can play a significant role in the exchange rate policy. More generally, a policy of transparency (actual and oral interventions) has greater effect than does a policy of secrecy. The results indicate that the effects are achieved mainly through the coordination channel and the signalling channel. Moreover, the effect is greater when policies involve a financial cost (risk), suggesting that simple announcements can be considered as only an imperfect substitute for actual interventions.

Event Studies in Emerging Markets

Leon and Williams (2012) contribute to the literature on the effects of intervention by analysing a unique daily dataset for the Dominican Republic, covering the period from 1997 to 2005, thereby providing a case study for small developing and emerging markets. A matched-sample test shows that sterilized intervention by the central bank can produce short-term effects with regard to the direction and reversal of exchange rate movements. The authors also use alternative event window definitions and alternative criteria to check the robustness of their results for the intervention effects. Their paper finds that during the sample period the Dominican Republic authorities were following a policy of leaning against the wind, aimed at either smoothing the exchange rate or reversing the trend direction, and that they were successful in keeping the exchange rate within a 'target' corridor. Furthermore, the results reveal two objectives of intervention in the Dominican foreign exchange market, namely ensuring and maintaining export competitiveness. The findings suggest that the authorities intervened in part due to the 'fear of floating', in particular fear of strong appreciation that could conflict with their objective of ensuring competitiveness. In addition, the results imply that interventions can be used effectively in emerging market economies and developing countries to contribute towards maintaining export competitiveness, while containing imported inflation. These findings constitute an interesting case study, suggesting that intervention can be an appropriate policy tool in some small open and emerging market economies.

There is great controversy as to which exchange rate model should be used or which channel should be considered when measuring the effects of exchange rate policy. Since most of the literature relies on structural models to address the identification problem, the validity of the results largely depends on how accurate the assumptions are in describing the full extent of the economy. Using an event study approach, Echavarría et al. (2013) compare the effects of different types of central bank intervention for the Colombian case during the period 2000-2012, without imposing restrictive parametric assumptions and without the need to adopt a structural model. Following Fatum and Hutchison (2003), they define four criteria to evaluate the effects of intervention: direction, reversal, smoothing, and matching. Echavarría et al. (2013) find that all types of intervention (international reserve accumulation options, volatility options and discretionary) were successful according to the smoothing criterion, with volatility options having the strongest effect. Results are robust when using different window sizes and counterfactuals. Two counterfactual exercises are conducted. First, they consider the evolution of the Brazilian exchange rate in periods corresponding to pre- and post-Colombian volatility interventions. Second, they consider periods in which volatility options should have been conducted if the intervention rule was in place, but were not, because the board of the central bank decided to suspend interventions in that period.

7.4.2 An Event Study Methodology for this Research

In this section, we begin by defining the length of the intervention event, or the ‘event window’. This comprises the pre-event days (also known as the estimation

window), the event day or days, and the post-event days (MacKinlay, 1997). Thereafter, some measure of a successful event is established.

The reason for choosing the event study approach to analyse intervention is that communication tends to happen in clusters. In certain periods several interventions may occur within a few days, while on other days there are no interventions (MacKinlay, 1997). The most likely explanation for this lies in the fact that monetary authorities often continue to use sequent interventions until they achieve a certain objective or else realize the efforts are in vain.

In finance, many events, such as earnings announcements or issuance of new debt, may take place on a single day. However, it is problematic to define each single day on which exchange rate communication occurs as a separate event. The pre- and post-event windows allow us to compare exchange rate movements around the defined event. Since the central bank often intervenes on consecutive days, a one-day event definition would lead to other one-day events happening within the pre- and post-event windows around one-day events. Therefore, exchange rate movements around one-day events might be caused by other one-day events occurring during the pre- and post-event windows. This would make the event study useless. For example, in the period 18-24 May 2007, exchange rate communications between the PBOC governor and the US Treasury Secretary occurred on six consecutive days, all around the theme of appreciation of the Chinese yuan. These six days should naturally be viewed as a single event.

Another important issue is the length of the event window. On the one hand, the longer the event window is, the more interventions will be clustered. If the event period is set too long, then it may put together interventions that should belong to different intervention episodes. On the other hand, if the event period is set too short, then it may separate into different events interventions that should belong to one intervention episode. Furthermore, too-short event periods may lead to a number of overlapping event windows. When selecting the appropriate length of event window, we also need to decide how many consecutive days of no intervention should be included. Finally, we define an event as a period of days with exchange rate communication tending in one direction, pushing for either appreciation or depreciation, and perhaps including a number of days without intervention.

Following Hutchison (2002), Fatum and Hutchison (2003), and Fratzscher (2012), we set the lengths of the pre- and post-event windows to be two, five, ten and fifteen days. This variety of event window length also means that the results can be employed in the robustness checks for different model specifications.

Following Fatum and Hutchison (2006), Fratzscher (2008), and Echavarria et al. (2013), we look at the dimensions of the effects of an intervention. Specifically, these dimensions involve intervention outcomes in relation to exchange rate changes (Δs) before ('pre'), after ('post') and during the event ('eve'); the average exchange rate change $\overline{\Delta s}$; and the event type or objective of the intervention event (I). We standardize exchange rate return by an estimated standard deviation for RMB exchange rate, as one solution to the heteroscedasticity is to standardize return

(Ederington et al., 2015). Based on Jaffe (1974), Mandelker (1974) and Patell (1976), we calculate standardized returns as follows:

$$\Delta s_t = er_t / \sigma_t \quad (7.4)$$

where er_t is RMB exchange rate return ($\log RMB_t - \log RMB_{t-1}$), and σ_t is an estimate of the standard deviation of the er_t .

To capture different directions of exchange rate movements, we set $I < 0$ to indicate an attempt to strengthen the domestic currency and $I > 0$ an attempt to weaken it. The ‘event’ type is used when investigating whether the direction of change to the RMB exchange rate is related to the interventions during the event; that is, whether or not an oral intervention leads to strengthening of the Chinese yuan:

$$(\Delta s^{eve} > 0, I > 0) \text{ or } (\Delta s^{eve} < 0, I < 0) \quad (7.5)$$

Frankel (1994) argues that a suitable criterion to determine whether exchange rate movement is in the direction desired by the central bank is simply whether the direction of the movement is the same as the direction entailed in the central bank’s intervention operation. For example, intervention carried out by selling the foreign currency should lead to a drop in its price. If the actual price of the foreign currency on the foreign exchange market declines, then one can say that the exchange rate movement is in the direction desired by the central bank. Therefore, in this research,

the ‘direction’ dimension is defined as positive if the exchange rate movement over the post-event window is in the desired direction, and negative otherwise:

$$(\Delta s^{post} > 0, I > 0) \text{ or } (\Delta s^{post} < 0, I < 0) \quad (7.6)$$

The next dimension of the intervention effects, ‘reversal’, refers to whether the intervention succeeds in appreciating (depreciating) the currency after the event if the exchange rate had been depreciating (appreciating) before the event:

$$(\Delta s^{post} > 0, I > 0 \text{ if } \Delta s^{pre} < 0) \text{ or } (\Delta s^{post} < 0, I < 0 \text{ if } \Delta s^{pre} > 0) \quad (7.7)$$

Although the fourth dimension, ‘smoothing’, also considers the pre-event period, it is less demanding. This concept investigates whether intervention has reduced or smoothed the strength of the pre-event exchange rate movements:

$$(\Delta s^{post} > \Delta s^{pre}, I > 0 \text{ if } \Delta s^{pre} < 0) \\ \text{or } (\Delta s^{post} < \Delta s^{pre}, I < 0 \text{ if } \Delta s^{pre} > 0) \quad (7.8)$$

Overall, testing of the reversal dimension is the most demanding of the four tests. This is because the direction test does not consider the pre-event period, and the smoothing test does not require the exchange rate to appreciate after intervention by the central bank.

It is natural to begin by considering the application of parametric tests to check the effect of oral intervention. However, parametric tests are valid only if the variable's distribution is normal. It is known that distribution of the daily changes of the exchange rate departs from the normal distribution. Results of formal statistical analysis of the intervention variable are presented in Table 7.4. From the table, we can see that the exchange rate change variable fails to pass the JB normality test. In addition, the skewness is smaller than 0 and the kurtosis is far away from 3. This evidence all points to the eventuality that the distribution of daily changes of exchange rate is not normal. In this case, parametric tests are not appropriate. However, we still use parametric tests, together with nonparametric tests. We can then compare the results of the two types of test.

Table 7.4 Descriptive Statistics for Exchange Rate Changes

	Obs.	Mean	Std.Dev.	Skewness	Kurtosis	Jarque-Bera
Oral intervention	2087	-0.001	0.007	-0.131	7.813	2020.421 [0.000]*

Notes: * means significance is at the 99% level.

We then choose the nonparametric test for our model, which does not require the distribution to be normal. Table 7.5 gives the details of parametric and nonparametric tests. We use two statistical tests, the sign test and the rank test, in our nonparametric estimation. The reason for using the sign test is that, unlike the Wilcoxon test, it does not assume a symmetric distribution. In addition, Mood's

Median test focuses on testing whether the medians of two or more groups differ, while the Mann-Whitney test and Friedman test need two samples. The nonparametric sign test is used to test whether or not two groups are equally sized. Also called the binominal test, the sign test is based on the plus and minus sign of the observation. The null hypothesis is that two populations are equal or are equal in their central tendency. In our model, we employ the nonparametric sign test to investigate whether there is any difference between the exchange rate movements before and following the intervention events in terms of the event and direction. Following the generalized sign test (Brown and Warner, 1980, 1985), our null hypothesis is that the number of positive values ('success') (n_+) is the same as the number of negative values ('non-success') (n_-). If the hypothesis is correct, the probability of successful events is the same as that of non-successful events. A sign test based on a binomial distribution checks whether the probability of a 'successful event' (p) is greater than 0.5 ($n_+ \sim binomial(n, p = 0.5)$), where n is the total number of events.

Table 7.5 Description of Nonparametric and Parametric Tests

Nonparametric tests	Alternative parametric tests
Sign test	1-sample Z-test, 1-sample t-test
Wilcoxon test	1-sample Z-test, 1-sample t-test
Mann-Whitney test	2-sample t-test
Rank test	One-way ANOVA
Mood's Median test	One-way ANOVA
Friedman test	Two-way ANOVA

Notes: ANOVA, which can compare means of different groups, is analysis of variance.

The sign test is a relatively weak test, since it tests the pair value below or above the median only, but does not measure the pair difference. There is another

nonparametric test, known as the rank test. Based on the Wilcoxon rank test and developed by Corrado (1989) and Corrado and Zivney (1992), the rank test, like the sign test, does not require distribution symmetry (Dutta, 2014). The null hypothesis of this test is that the rank of exchange rate changes is equal to the mean of total observations ('success'). Under the null hypothesis, the rank of exchange rate changes is uniform distribution (Corrado, 1989). We use the rank test to check the effect of intervention in terms of exchange rate reversal and smoothing. The rank test statistic is given by:

$$R = \frac{K_t - \bar{K}}{S(K)} \quad (7.9)$$

where K_i is the rank of exchange rate changes; \bar{K} is the average rank ($\bar{K} = \frac{T+1}{2}$, T is the number of observations); $S(K)$ is the standard deviation, and is calculated as:

$$S(K) = \sqrt{\frac{1}{T} \sum_{t=1}^T (K_t - \bar{K})^2} \quad (7.10)$$

This statistic is distributed asymptotically as unit normal.

7.5 Results of the Event Study

7.5.1 Results from Parametric Tests

In this section, we evaluate whether China's interventions are successful based on the criteria given above. Table 7.6 displays the numbers of China's exchange rate communication events. Table 7.7 reports the results for the success of exchange rate communication in the whole sample period. In each table the columns from left to right show the different event window lengths: 2, 5, 10 and 15 days. The rows display the total number of communications, the number of successful communications (as a percentage), and the probability value for the four criteria. To study the first two criteria, event and direction, we use sign test based on a binomial distribution; the hypothesis is that the number of successful events is the same as the number of non-successful events. The remaining criteria are tested by the rank test; here, the hypothesis is that the rank of exchange rate changes is equal to the mean of total observations.

Table 7.6 Number of Exchange Rate Communication Events

	2 ^a	5 ^b	10 ^c	15 ^d
Total Comm. Num.	270	187	120	85
$IO_t = 1$	100	76	57	44
$IO_t = -1$	170	111	63	41

Notes: a. pre- and post-event window length is 2 days;
b. pre- and post-event window length is 5 days;
c. pre- and post-event window length is 10 days;
d. pre- and post-event window length is 15 days.

As can be seen from Table 7.6, for the 2-day pre- and post-event windows the number of appreciating communications ($IO_t = -1$) is larger than that of

depreciating communications ($IO_t = 1$), accounting for 63% of the total. However, the difference between the numbers of appreciating and depreciating communications decreases from the 2-day event window to the 15-day event window, where the numbers of the two types become almost equal. In order to avoid overlapping communication days, the longer the event window length is, the more communication days are included. For example, in the 15-day event window, we put 12 communication days into one event, which runs from 12/04/2007 to 21/06/2007. According to the trend of difference between the numbers of appreciating and depreciating events, we find that appreciating communication is more compact. In other words, the authorities, especially the US President and Treasury Secretary, try to appreciate the RMB exchange rate with greater pressure.

Table 7.7 Results of One-Sample T Tests for Event and Direction and ANOVA Tests for Reversal and Smoothing

Event Window Length			2	5	10	15
Total Num.	$IO_t = 1$		100	76	57	44
	$IO_t = -1$		170	111	63	41
Event	$IO_t = 1$	Success %(Num.)	46%(46)	50%(38)	81%(26)	34%(15)
		P-Value	0.387	0.117	0.389	0.326
	$IO_t = -1$	Success %(Num.)	52%(88)	52%(58)	60%(38)	71%(29)
		P-Value	0.234	0.318	0.320	0.147
Direction	$IO_t = 1$	Success %(Num.)	45%(45)	37%(28)	28%(16)	34%(15)
		P-Value	0.833	0.423	0.000*	0.006*
	$IO_t = -1$	Success %(Num.)	49%(83)	55%(61)	75%(47)	78%(32)
		P-Value	0.323	0.001*	0.000*	0.000*
Reversal	$IO_t = 1$	Success %(Num.)	29%(29)	37%(16)	25%(14)	20%(9)
		P-Value	0.988	0.249	0.000*	0.436
	$IO_t = -1$	Success %(Num.)	19%(32)	16%(18)	16%(10)	15%(6)
		P-Value				

		P-Value	0.902	0.000*	0.000*	0.000*
Smoothing	$IO_t = 1$	Success %(Num.)	45%(45)	45%(34)	56%(32)	43%(19)
		P-Value	0.987	0.009*	0.000*	0.006*
	$IO_t = -1$	Success %(Num.)	30%(51)	27%(30)	17%(11)	20%(8)
		P-Value	0.323	0.001*	0.000*	0.000*

Notes: * means that p-value is significant at the 95% level.

Based on Table 7.7, we find that interventions have no effects according to the event criterion, because there are no significant p-values for this criterion. Another finding is that the intervention is more effective in the long term than in the short term. The significances in 10-day and 15-day event window lengths are larger than in 2- and 5-day event window lengths. We also use nonparametric tests to prove our finding.

7.5.2 Results from Nonparametric Tests

Table 7.8 Results of Sign Tests for Event and Direction and Rank Tests for Reversal and Smoothing

Event Window Length			2	5	10	15
Total Num.	$IO_t = 1$		100	76	57	44
	$IO_t = -1$		170	111	63	41
Event	$IO_t = 1$	Success %(Num.)	46%(46)	50%(38)	81%(26)	34%(15)
		P-Value	0.484	0.088	0.596	0.050*
	$IO_t = -1$	Success %(Num.)	52%(88)	52%(58)	60%(38)	71%(29)
		P-Value	0.701	0.704	0.131	0.012*
Direction	$IO_t = 1$	Success %(Num.)	45%(45)	37%(28)	28%(16)	34%(15)
		P-Value	0.368	0.029*	0.001*	0.050*
	$IO_t = -1$	Success %(Num.)	49%(83)	55%(61)	75%(47)	78%(32)
		P-Value	0.818	0.343	0.000*	0.001*
Reversal	$IO_t = 1$	Success %(Num.)	29%(29)	37%(16)	25%(14)	20%(9)
		P-Value	0.001*	0.001*	0.000*	0.002*
	$IO_t = -1$	Success %(Num.)	19%(32)	16%(18)	16%(10)	15%(6)
		P-Value	0.007*	0.000*	0.000*	0.000*
Smoothing	$IO_t = 1$	Success %(Num.)	45%(45)	45%(34)	56%(32)	43%(19)
		P-Value	0.160	0.005*	0.001*	0.012*

$IO_t = -1$	Success %(Num.)	30%(51)	27%(30)	17%(11)	20%(8)
	P-Value	0.424	0.211	0.000*	0.000*

Notes: * means that p-value is significant at the 95% level.

Table 7.8 shows the results from the sign tests based on the event and direction of exchange rate movements, and results from the rank test based on the reversal and smoothing criteria for successfulness of an event. From these results, we can find that: 1) the exchange rate communication events have no effect according to the event criterion; 2) all event window lengths are significant in terms of the reversal effect; 3) the longer the event window length is, the more significant the oral intervention effects are. Compared with the results from parametric tests, we find that nonparametric tests have more significant p-values.

For the event dimension, both appreciating and depreciating communications have no effects. The only significant communication effects are at the 15-day event window length. This means that China's exchange rate communication cannot impact the exchange rate movement during the event. This finding is the same as that from the parametric tests. Another notable phenomenon is that, in terms of the direction and smoothing dimensions, oral intervention events are only significant at the 95% level at the 10- and 15-day event window lengths. This means that the communication intervention has a property of leaning against the wind, and the strength of pre-event exchange rate movements tends to diminish two weeks after the oral intervention. Reversal is the only dimension for which the communication events are significant at all event window lengths. In other words, if the exchange rate was depreciating before the event, oral intervention can be effective in

appreciating the RMB after the event; alternatively, if the currency was appreciating before the event, the intervention can be effective in depreciating the RMB.

Based on the difference between the results at different event window lengths, we can see that the effects of oral intervention via exchange rate communication are more obvious in the longer term than in the short term. Communications have more significance in the 10- and 15-day event window lengths, and especially in the latter. This suggests that, in the Chinese context, oral intervention via exchange rate communication would have more effect on the RMB exchange rate after two weeks. This finding further confirms the robustness of the parametric test results.

7.5.3 Specific Results for Domestic and External Communications

Oral intervention in the RMB exchange rate has two sources: domestic and external. The US authorities have for a long time tried to pressurize China to appreciate the RMB exchange rate. Here, we examine to what extent exchange rate communications initiated by the US may influence the RMB exchange rate. In particular, the US Treasury is required by Congress to submit a half-yearly examination report on China's currency issues. If China were found to be manipulating the RMB exchange rate, US law requires that the US government must impose punitive tariffs on imports from China. In order to avoid this punitive action, the Chinese government seems responsive to the oral intervention via such reports and would, in most cases, appreciate the exchange rate secretly.

Table 7.9 Parametric and Nonparametric Tests for Domestic and External Communications

Type			Domestic		External	
Event Window Length			2	15	2	15
Total Num.	$IO_t = 1$		100	44	0	0
	$IO_t = -1$		78	48	119	41
Event	$IO_t = 1$	Success %(Num.)	46%(46)	34%(15)		
		Parametric test	0.706	0.868		
		Nonparametric test	0.484	0.050*		
	$IO_t = -1$	Success %(Num.)	46%(36)	56%(27)	55%(65)	71%(29)
		Parametric test	0.669	0.914	0.012*	0.010*
		Nonparametric test	0.571	0.470	0.359	0.012*
Direction	$IO_t = 1$	Success %(Num.)	45%(45)	34%(15)		
		Parametric test	0.031*	0.013*		
		Nonparametric test	0.368	0.050*		
	$IO_t = -1$	Success %(Num.)	51%(40)	77%(37)	47%(56)	73%(30)
		Parametric test	0.091	0.000*	0.160	0.001*
		Nonparametric test	0.910	0.000*	0.582	0.005*
Reversal	$IO_t = 1$	Success %(Num.)	29%(29)	20%(9)		
		Parametric test	0.000*	0.000*		
		Nonparametric test	0.005*	0.001*		
	$IO_t = -1$	Success %(Num.)	21%(16)	15%(7)	18%(21)	10%(4)
		Parametric test	0.004*	0.000*	0.005*	0.000*
		Nonparametric test	0.017*	0.000*	0.017*	0.000*
Smoothing	$IO_t = 1$	Success %(Num.)	45%(45)	43%(19)		
		Parametric test	0.031*	0.013*		
		Nonparametric test	0.317	0.035*		
	$IO_t = -1$	Success %(Num.)	33%(26)	15%(7)	29%(34)	15%(6)
		Parametric test	0.091	0.000*	0.160	0.001*
		Nonparametric test	0.821	0.000*	0.774	0.003*

Notes:* means that p-value is significant at the 95% level.

Table 7.9 displays the results of parametric and nonparametric tests for domestic and external communications. For both tests, there are more significant results for all dimensions of intervention effects in the 15-day event window length. This proves the robustness of the finding that exchange rate communication has more effect on exchange rate movements after two weeks. Reversal is the only dimension of the intervention effects for which the communication events are significant at all event window lengths. Based on the results in Table 7.9, the appreciation exchange rate communication from the US can influence the RMB exchange rate movements, as the table shows that communication events are significant. The Chinese government is responsive to oral pressure from the US, and would initiate the RMB appreciation after some delay, perhaps about two weeks.

7.5.4 Volatility Analysis

Government intervention usually has two main objectives: to change the level of the exchange rate in a certain direction and to calm excessive volatility (Sarno and Taylor, 2001; Utsunomiya, 2013). Previous sections in this chapter are mainly concerned with the first objective, i.e. changing the level of the exchange rate. Next, we examine the effects of oral intervention on the volatility of China's currency. For this purpose, it is pertinent to use open, closed, high and low daily exchange rates from 2005 to 2013. The data are obtained from Bloomberg and the event window lengths are set to be 2 days and 15 days. We investigate the volatility in 207 pre-event and post-event periods for the 2-day event window length, and in 28 periods for the 15-day event window length. More specifically, we calculate the range-based variance of the USD/CNY exchange rate during the 48 hours (2-day windows) or

360 hours (15-day windows) before and after each event, respectively. The formula (Garman and Klass, 1980) to calculate the range-based variance of the USD/CNY exchange rate is shown below:

$$\sigma_{rb}^2 = 0.5[\ln(\frac{H_t}{L_t})]^2 - [2 \ln(2) - 1][\ln(\frac{C_t}{O_t})]^2. \quad (7.11)$$

where σ_{rb}^2 is the range-based variance of the exchange rate; H_t is the highest price of the t^{th} trading day; L_t is the lowest price of the t^{th} trading day; C_t is the closing price of the t^{th} trading day; O_t is the opening price of the t^{th} trading day.

For the event window length at 15 days, 14 events have lower post-event volatility, while for the 2-day event window length, 121 events have lower post-event volatility. We use the Kruskal-Wallis test to study whether the oral intervention can reduce volatility. The null hypothesis of the Kruskal-Wallis test is that the mean ranks of the two groups are the same. In our study, the null hypothesis is that pre-event volatility is the same as post-event volatility. The ranks are always whole numbers from 1 to N. We check the variation ranks among the groups:

$$SST = SSG \text{ for the ranks} \quad (7.12)$$

where SST is the total variation and SSG is the variation among the groups. The test statistic is given by:

$$H = \frac{12}{N(N+1)} \sum \frac{RA^2}{n_i} - 3(N + 1), \quad (7.13)$$

where N is the total number of observations, n_i is the number of observations in group i , and RA is the rank of observation. Table 7.10 shows the results of difference of volatilities between the pre- and post-event periods at 2- and 15-day event window lengths. Based on the results in Table 7.10, we do not find evidence of a link between oral intervention and volatility reduction, as no variables are significant in the test outcome.

Table 7.10 USD/CNY Exchange Rate Volatility during Pre- and Post-Event Windows

Event Window Length		2	15
Total Num.		207	28
Event	Success %(Num.)	58%(121)	50%(14)
	P-Value	0.978	0.935

While we find no link between oral intervention events and exchange rate volatility, it should be noted that this result might be influenced by certain factors. The exchange rate communication data used in this chapter are available only at daily frequency: we cannot know the exact time within the day when the communication happened, nor the length of communication time. In other words, the pre-event volatility window may end before the first day of the communication event; the communication event may take place over successive days; or, the post-event volatility window may start after the event has ended.

Then, we test whether successive oral interventions can reduce volatility. Table 7.11 shows the result regarding reduction of volatility when two or more successive oral interventions happen. Based on Table 7.11, we find evidence that successive oral interventions can reduce volatility. Therefore, the central bank tries to calm excessive volatility by successive oral interventions.

Table 7.11 Effects of Successive Interventions on Volatility

	Two or more successive oral interventions
Total Num.	48
Success %(Num.)	58%(28)
P-Value	0.020*

Notes: * means that p-value is significant at the 95% level.

7.6 Conclusions

This chapter evaluates China's exchange rate communication and its efficacy on the level and volatility of the RMB exchange rate. Daily data are employed to investigate the oral intervention effects during the sample period from 22 July, 2005, when the most recent reform was launched to sever the rigid link between the RMB and the USD and allow the RMB to move within a certain band, to 22 July, 2013, when the most recent data are available to this research. The chapter employs an event study approach. In the empirical examination, we postulate that the effects of an intervention event can have four dimensions, namely event, direction, reversal, and smoothing.

Given the property of the distribution of our datasets, this research uses parametric and nonparametric tests for the four dimensions of the oral intervention effects. The two samples for tests are constructed at the pre- and post-event window lengths of two, five, ten and fifteen days. In general, the results show that oral intervention can have effects on the level of the Chinese exchange rate. While the outcome shows no significant effects in the event dimension, all event window lengths are significant in terms of the reversal effect. Finally, the effect may vary with the event window length. Compared with the 2- and 5-day event window lengths, communications have more significant effects at the 10-day, and particularly the 15-day event window lengths, suggesting that in the Chinese context the most significant intervention effects would occur about two weeks after the exchange rate communication. We also find that nonparametric tests have more significant effects than parametric tests.

Findings with regard to the international aspects of the exchange rate communication provide further insights on China's exchange rate intervention. Evidence of China's response to calls from the US authorities for changes in exchange rate policy, especially for exchange rate appreciation, confirms that the Chinese government is generally responsive to US pressure for RMB appreciation. However, the response is moderately reluctant, as the authority would quietly appreciate the exchange rate after a delay of around two weeks.

This chapter also sheds light on another objective of China's intervention, namely calming excess volatility. We use a range-based variance model to calculate the variance and employ the Kruskal-Wallis test to study whether or not exchange rate

communication can reduce volatility. We find that, regardless of the event window length, there is no evidence of a link between isolated oral intervention and volatility reduction. However, the results show that successive oral intervention can reduce volatility.

Chapter 8

Conclusions

8.1 Main Findings

The aim of this thesis is to improve the understanding of China's exchange rate policy by offering a comprehensive investigation of official foreign exchange intervention as a key plank of China's exchange rate regime. China's foreign exchange interventions are classified into three main categories, namely CB intervention, CPR intervention and oral intervention. With this classification, this dissertation researches the behaviour, strategy and efficacy of China's foreign exchange intervention operations.

Study of foreign exchange intervention has always been a challenging task and this is especially so for the Chinese case because of the data availability issue and the complexity of the intervention regime. This thesis employs two methods to collate the intervention data. First, the CB intervention and oral intervention are identified through searching an extensive range of news media reports from the Factiva and Reuters China databases. Second, we construct a CPR intervention index. These data enable us to establish the intervention days and to test for the determinants and effects of interventions.

Following the introduction of the developments of China's exchange rate regime in recent decades, Chapter 4 begins by testing the determinants of China's CB intervention during the whole sample period. We divide these determinants into three sets: basic determinants, domestic market determinants and foreign exchange market determinants. The empirical model for testing the significance of the determinants is the bivariate probit model.

CB intervention happens when the central bank issues buying or selling instructions or guidance via the state-owned banks, or engages directly in purchase or sale of foreign currencies. The findings show that the PBOC has a strategy that conducts intervention in a leaning-against-the-wind fashion in the medium term, while leaning-with-the-wind intervention is used in the short term.

Analysing the dummy variables for volatility on the days with above average level of volatility and the days when the Chinese RMB is in appreciation or depreciation, we find evidence that China's CB intervene is deployed to constrain volatility of the RMB exchange rate movement, indicating that one of the PBOC's policy objectives is to ensure there are no big swings in the RMB exchange rate.

A related interesting finding is that deviations of the current exchange rate from the central parity would powerfully prompt the PBOC to intervene, highlighting the central role of the parity in China's management of the exchange rate. In addition, the empirical evidence suggests that large deviations from the central parity could trigger purchase intervention, and that the sale intervention is addressed at small deviations from the central parity.

Study of the CB intervention also sheds light on the behaviour of China's intervention in different sub-sample periods spanning the global financial crisis. Evidence shows that the main objective of the PBOC during the crisis was to steady the Chinese foreign exchange market.

In Chapter 5, we examine what factors would trigger China's CPR intervention. To construct the CPR intervention index, the indirect fair value approach is employed to estimate the equilibrium RMB exchange rate. Based on China's practice of setting the central parity rate, we test to what extent the USD/CNY exchange rates proposed by designated market makers, the broad currency index and the yield curve spread could influence the CPR intervention for the whole sample period from 22 July 2005 to 22 July 2013. Determinants of CPR intervention are tested in a Bayes Tobit model. The time-varying drivers behind CPR intervention across different sub-samples, and between high and low intervention, are also studied.

CPR intervention is conducted through the setting of the central parity rate. Results show that the proposed exchange rates by market makers, the broad currency index and the yield curve spread are significant triggers of CPR intervention. The proposed exchange rates by market makers reflect the market evaluation of the RMB exchange value and hence the mean of these RMB evaluations can be deemed as a proxy for the market exchange rate; the broad currency index is a proxy for international currency movements and the yield curve spread embodies macro conditions of the Chinese economy. We find evidence that, in the context of CPR setting, the PBOC follows a leaning-against-the-wind intervention strategy since the

sign to the coefficient on the mean of the proposed exchange rates by market makers is negative, suggesting that the PBOC employs intervention to dampen or even reverse deviations of the mean value of market makers' proposed exchange rates from the fair value of RMB. In addition, both bad (good) conditions of international foreign exchange markets and macro conditions of the Chinese economy could influence high (low) CPR intervention. In terms of magnitude of the effects on PBOC's CPR intervention decision, the yield curve spread is the least important factor, while the broad currency index is the most important factor.

The driving forces behind daily CPR intervention are also found to be time-varying. The significances of determinant factors vary in different sub-samples, and also between high and low intervention reaction functions in the Tobit regression. The evidence across different sub-samples indicates that during high intervention, the PBOC's decision on price intervention takes into consideration of international foreign exchange conditions since the broad currency index is significant and positive. The yield curve spread variable is insignificant in high intervention equation but is significant for low intervention. This suggests domestic economic conditions have some effects on PBOC's price intervention decision, but only in the in-frequent intervention period.

In investigating efficacy of China's interventions in Chapter 6, we use threshold GARCH models to conduct the tests. The evaluation here mainly involves CB and CPR interventions. First, Hansen's model-based bootstrap procedure is applied to determine the number of regimes in the whole sample and the three sub-samples. Then, we use Tsay's arranged autoregression method to get the order of the lag

structure (p) for the AP model and the optimal delay parameter, and apply Chan's test outcome to obtain the threshold value and the RSS from which we can find how many regimes existing in the samples. Third, we test whether or not China's intervention and intervention frequency can move the USD/CNY exchange rate in the desired direction and reduce exchange rate volatility in the whole sample. Finally, this Chapter examines the different effects of interventions across sub-samples.

It is found that the Chinese central bank adopts the strategy of leaning-against-the-wind interventions to influence exchange rate movements. CPR intervention can affect exchange rate levels when the RMB exchange rate is appreciating. However, when the RMB depreciates, only CB intervention impacts on the exchange rate level. For intervention frequency, results show that low-frequency CPR intervention has stronger effects on the exchange rate level than that low-frequency CB intervention has in periods when the yuan is appreciating. Furthermore, both CPR and CB interventions can increase exchange rate volatility. But, high-frequency intervention can reduce the volatility, especially when the yuan appreciates.

In analysing the time variation of China's intervention effects on exchange rate levels and volatility, evidence suggests that before the global financial crisis the effects were stronger when the exchange rate was appreciating, while after the crisis interventions have large effects when the exchange rate depreciates. During the global financial crisis when China temporarily re-pegged the RMB exchange rate, only CB intervention has an effect on exchange rate levels. In contrast, CPR intervention has no such an effect. For volatility, both CB and CPR interventions would increase volatility of the RMB returns. Regarding intervention frequency,

only high-frequency CB intervention could have significant effects, and on both exchange rate levels and volatility.

Oral intervention is a special form of China's intervention, which is studied in Chapter 7 in the event study approach. Using newswire reports, we get the data for both domestic and external events that have a bearing on the RMB exchange rate. In these events, Chinese monetary authorities communication to state banks in forms of formal and informal meetings, telephone conversations and policy briefings et al. to instruct domestic units to do what the central bank wishes. Tests for whether domestic oral intervention is successful in influencing exchange rate levels are conducted against four criteria: event, direction, reversal and smoothing. Sign and rank tests are based on 2-, 5-, 10- and 15-day event window lengths. For international events that involve the RMB, especially those in the USA, we assume that around these events Chinese authorities may give directions in various forms to domestic banks on things to note and actions to be taken. We then examine whether the RMB is responsive to such events. Finally, for volatility, the Kruskal-Wallis test is employed to investigate whether the oral intervention can calm excessive volatility.

In general, evidence indicates that intervention via communications can influence levels of the RMB exchange rate in the desired direction. Of the four criteria, all event window lengths are significant in the reversal dimension, while there are no significant effects against the event criterion. We also find that oral intervention has more significant effects at 10- and 15-day event windows than that at the 2- and 5-day event window lengths. This means that the effects of oral intervention on exchange rate levels would surface about one to two weeks after an exchange rate

event. For intervention's effect on volatility, regardless of the event window length, there is no evidence that standalone oral intervention can reduce volatility of the RMB exchange rate. However, if the oral intervention is successive, we find that it can reduce volatility.

In addition to domestic occasions, we also consider external events where pressures are exerted on China's exchange rate policy, usually calling for appreciation of the RMB. Notable examples of such events include speeches by American political heavyweights or congressmen, high level Sino-USA meetings, or ministerial reports. The results show that while China has publically stood firm to external pressure, its exchange rate policy is responsive to international calls for RMB appreciation. Typically, the Chinese government would not make an instant policy response to external events, but quietly it would allow the exchange rate to adjust (usually appreciation) after a delay of around two weeks.

8.2 Findings between Advanced Countries and China's Market

The main findings of this thesis are consisted of two major parts, the first of which concerns with determinants of China's intervention and the second involves the effects of intervention and its efficacy. It would be beneficial to further examine these findings in the comparative perspective with findings from previous research on that of other countries, especially advanced countries.

The Chinese intervention takes three forms, which are CB, CPR and oral interventions. In comparison however, intervention in advanced countries, including the US, EU

countries or Japan, normally takes only two forms and intervention through direct control over and adjusting the CRR exchange rate is rare. This is largely due to the fact that there are limited channels of intervention existing in China and so the PBOC has to resort to more forms of intervention to hide its operations from the market traders.

Although China's intervention increases volatility of the exchange rate movements, we find that sequential intervention can reduce the volatility. Especially we show that combined with other forms of intervention, oral intervention can be effective in reducing the volatility. This finding is a new contribution to the literature.

Another important difference between interventions in China and in other countries is about the oral intervention. China's oral intervention is shown to be responsive to outside pressures, especially those from the US government. In other advanced countries, this is not always the case since direct international pressures are rare for those countries, except for a few countries like Japan and Germany.

Similarities also exist in both China and other advanced economies. For example, in both China and its counterparts, official intervention usually follows the leaning-against-the-wind strategy. Second, they have all experienced varying effects of intervention on exchange rate movements due to regime shifts in the exchange rate arrangements in the recent decades. It is also common to both of them that, low-frequency intervention can be effective on changing exchange rate levels, while high-frequency operation can reduce volatility of exchange rate changes arising from official intervention.

8.3 Implications of the Research

This research contributes to the debate on China's exchange rate by offering an avenue for a better understanding of official intervention in China, which is a key feature of the country's foreign exchange rate policy. Several important implications can be drawn from the research of this thesis. First, research findings of the thesis call on the Chinese monetary authorities to upgrade their intervention objectives and strategy. In examining different types of intervention, this thesis shows that the basic intervention strategy that the Chinese policy-makers employ is to play a decisive role in leaning against the wind while ensuring that there are no large swings in the RMB exchange rate. However, not every movement of the exchange rate is destabilising and not every move of the exchange rate needs to be reversed. In reality, on various occasions movements of the exchange rate are towards its equilibrium value, and in this case it does not make much sense to lean against the wind. Rather, the central bank should encourage or facilitate such reversion of the exchange rate to equilibrium.

With the development of modelling techniques, there have emerged several methods for determination of the equilibrium exchange rate, e.g. the IMF's new External Balance Assessment (EBA) Methodology (IMF, 2013). With increasingly refined model-based estimation of the equilibrium exchange rate, at least in broad directions, the central bank can judge whether the exchange rate movement is in the direction of moving away or towards equilibrium. As such, intervention by the central bank

can become “smarter”, or be more targeted at combating the destabilising movements of the exchange rate, rather than a cross-board leaning against the wind intervention.

Related with this is a further possible improvement in China’s CPR intervention, i.e. in providing the central bank with better informed decision on setting and adjusting of the central parity exchange rate as a way of intervention. At the time of this study, China’s benchmark exchange rate, the central parity exchange rate, is not model-based, but a product of a mixture of taking account of market opinions and the central bank’s discretion. This can be improved upon by adding the imputed equilibrium exchange rate based on model estimation for the central bank’s assessment of the desired level of the exchange rate. Adding this model-based equilibrium exchange rate will prove particularly useful when the central bank tries to initiate ‘smart intervention’, i.e. intervene when the exchange rate moves away from equilibrium and refrain from intervening when the exchange rate is moving towards equilibrium. In short, this will be helpful for the central bank to withdraw from the practice of intervention on all large movements of the exchange rate.

From these results, implications can be drawn for the demand and supply theory and for the principal- agent model. For the demand and supply theory, the intervention strategy follows the leaning-against the wind hypothesis. This means that when purchase (sale) intervention happens, the supply for foreign currency will decrease (increase) in the open market, and then the domestic currency against the foreign currency will depreciate (appreciate). In the principal agent model, the PBOC has

the information advantage. It can use the oral intervention which offers information to the market, the agents, such as the noise traders and fundamentalists, will change their expectations, and then the exchange rate will change under the influence.

8.4 Limitations and Avenue for Future Research

Despite the advances that this thesis has made in achieving a better understanding of foreign exchange intervention in China, this thesis has certain limitations. Addressing these limitations in turn present some promising avenues for future research.

First, this research is limited owing to the lack of government intervention information. Future work should dig out more relevant information in this area. Better information would allow for a more precise study, and comparison between the officially stated intention and the research evidence would provide critical insights on the Chinese foreign exchange policy.

Second, future work should continue the focus on the changes to China's exchange rate system. This research uses the time period from 2005 to 2013. However, since the end of that sample period there have been at least two further changes. One is the increasing of the RMB exchange rate band from 1% to 2% on March 17, 2014. The other is the improvement to the process of setting the central parity rate, implemented on 11 August, 2015. Future work should seek to find out the effects of these two changes on China's foreign exchange market.

Because of the data availability problem, it is not straightforward at the time of current research to conduct meaningful exploration of the possible channels through which Chinese intervention exerts its effects. However, with the development of the Chinese foreign exchange market and improved data collection, it may become possible for researcher to examine the channels including the order flow channel. With the presence of this microstructure channel, the central bank has superior information to other market traders. It is then will be interesting to find out whether and how the central bank would use this information advantage to shape the market.

Finally, interactions of foreign exchange intervention with other components of monetary policy are a very promising area for future research. As a tool of monetary policy, foreign exchange intervention interacts with other parts of monetary policy in various ways. These interactions would involve supply of base money, interest rates and transmission mechanism of monetary policy. Expounding on these interactions and their consequences certainly can better our understanding of China's exchange rate policy, but it can also shed critical lights on the working of the Chinese economy and its repercussions on the world economy.

Appendices

Table A. Maximum Likelihood Estimates of Garch (1,1)

Mean Equation $\Delta s_t = \beta_0 + \beta_1 \Delta s_{t-1} + \beta_2 \Delta s_{t-2} + \beta_3 Interest_t + \beta_4 GB_t + \beta_5 Int_{p,s,t-1} + \varepsilon_t$		
	Coefficient	Std.Error
β_0	0.0001**	4.767e-005
β_1	-0.140***	0.024
β_2	0.007	0.024
β_3	-2.343e-005	1.955e-005
β_4	-7.839e-005*	3.019e-005
β_5	-2.876e-005	4.861e-005
β_5	1.423e-006	5.804e-005
Variance Equation $h_t = \alpha_0 + \alpha_1 h_{t-1} + \alpha_2 \varepsilon_{t-1}^2 + \alpha_3 Interest_t + \alpha_4 GB_t + \alpha_5 Int_{p,s,t-1}$		
α_0	-0.358***	0.047
α_1	0.951***	0.003
α_2	0.025***	0.001
α_3	0.002	0.003
α_4	0.022**	0.005
α_5	0.004	0.011
α_5	0.007	0.012
Skewness		4.48
Kurtosis		39.041
$Q(20)$		5.575
$Q^2(20)$		0.295
Observation		2086

Notes: ***means the coefficient is significant at the 99% level; **means the 95% significant level and * means the 90% Significant level.

Table B. Maximum Likelihood Estimates of Asymmetric Garch (1,1)

Mean Equation $r_t = c_0 + \sum_{k=1}^p \theta_k r_{t-k} + \alpha_0(i_t - i_t^*) + \alpha_1 ST_t + (\beta_0 + \beta_1 \pi_t^{CPR}) CPR_t + \omega_0 + \omega_1 \pi_t^{CB} CB_t + u_t$		
	Coefficient	Std.Error
c_0	0.0087	0.0100
θ_1	-0.0380	0.0243
α_0	0.0010***	0.0003
α_1	-0.0055	0.0053
β_0	3.8459***	0.4716
β_1	-2.764***	0.7736
ω_0	0.0062***	0.0022
ω_1	0.0013	0.0064
Variance Equation $h_t = \Phi_0 + \Phi_1 h_{t-1} + \Phi_2 \varepsilon_{t-1}^2 + \lambda_0 CPR_t + \lambda_1 CB_t + \tau_0 \pi_t^{CPR} + \tau_1 \pi_t^{CB} + \varphi h_{t-1}$		
Φ_0	-5.46E-07	8.89E-07
Φ_1	0.7398***	0.0081
Φ_2	0.1702***	0.0226
λ_0	0.0407***	0.0028
λ_1	3.89E-05***	7.13E-06
τ_0	-5.68E-05***	1.29E-05
τ_1	0.0001***	2.18E-05
φ	-0.0220	0.0290
Skewness		-0.3414
Kurtosis		7.0916
$Q(20)$		0.043 (0.613)
$Q^2(20)$		0.078 (0.300)
Observation		2087

Notes: ***means coefficient is significant at 99% level; **means coefficient is significant at 95%; *means coefficient is significant at 90%. Numbers inside the brackets are asymptotic p-values.

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