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The Capital Control Effect On The Failure Of Covered Interest Parity In Asian Markets

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THE CAPITAL CONTROL EFFECT ON THE FAILURE OF COVERED INTEREST PARITY IN ASIAN MARKETS

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in

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by

Qing Ge

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Table of Contents

List of Figures

List of Tables

Abstract

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by

Qing Ge

This dissertation investigates factors related to the failure of covered interest parity by focusing on seven Asian emerging economies where they have both onshore deliverable forward and offshore non-deliverable forward. It implements the deviation from covered interest parity (CID) to proxy the capital control risk as to the primary risk factor and other subsequent risk factors. Among these seven countries and three types of forward maturities, capital control has a positive effect on the carry trade return, especially the strategy using onshore deliverable forward. The results are relevant to those emerging countries as they manage their capital flow and protect currency crashes.

The second part constructs an extended daily capital control index from Oct. 2010 to July 2019 and collect PBoC interventions for the same period to measure the failure of CID in China onshore and offshore markets. It finds that the level of CIDs of China FX markets is positively related to the capital control restrictions but not the government intervention. However, by applying an extended GARCH model, the volatilities of the CID are reduced by direct and indirect government interventions.

In the last part, my coauthor Penghao Cheng and I implement a model to explore Chinese onshore and offshore financial markets and fill the gap of the term spread differential of money market and CIP violation of currency market spillover effects. The empirical test uses a new flexible econometric method - Bayesian local projections. This Bayesian method can sensibly reduce the impact of compounded biases over the horizons and effectively deal with model misspecifications.

Thank you to my academic adviser Professor Michael Hutchison, who guided me in this process and the committee Professor Ken Kletzer, Chenyue Hu, Grace Gu who gave me useful suggestions.

I dedicate this dissertation to my coauthor, who helped me in the third part.

For my parents, who helped me in all things great and small.

This dissertation is dedicated to my wife, who encouraged me to pursue my dreams.

Acknowledgments

I want to appreciate my coauthor Penghao Cheng's contribution to my 3rd part. He implemented the new flexible econometric method - Bayesian local projections to the extended model to explore the term spread differential of money market and CIP violation of currency market spillover effects.

Part I

First Part

Chapter 1

Introduction

A carry trade is a common trade strategy within countries where investors borrow in low-interest-rate currencies and invest in high-interest-rate currencies. According to the uncovered interest parity (UIP) theorem, if investors are risk-neutral and have rational expectations, then exchange rates fluctuation will eliminate any profit arising from the differential in interest rates across countries. However, empirical studies show that UIP does not appear to hold in the data, [1] which is known as the "forward premium puzzle." Due to this puzzle, a carry trade accumulates profit before the global financial crisis across countries. However, from 2007 to 2009 the financial crisis beat the investors through the exceptional high FX volatility. After the crisis, the investors construct the carry trade through currency derivatives to hedge the exchange risk. Several types of research proved that CIP holds between developed countries but does not hold in emerging countries (Akram and Sarno [2008]; Mancini-Griffoli and Ranaldo [2011]) because of the convertibility restrictions and capital controls. Thus the carry trade vol-

[1] See Engel [1996] and Hodrick [2014] for reviews of the extensive literature documenting the failure of UIP

ume through offshore and onshore FX markets increased in the last decade. The global foreign exchange market turnover in emerging countries increase 210% from 2001 to 2013 reached a daily volume of US$ 879 billion. The carry trade using forward of emerging countries becomes an important research topic in international economics.

This paper investigates the factors of offshore non-deliverable forward (NDF) and onshore deliverable forward (DF) carry trade returns for currencies with NDF and DF contracts on a sample of 7 Asian emerging countries from September 2002 to June 2016. This paper has two aspects of motivation in this paper. For one thing, there is scarce empirical research on NDF and DF carry trade performance. A few researchers focus on the currencies that have both onshore and offshore forwards. Burnside et al. [2011] finds that volatility and skewness (or crash risk) factors have explanatory power of the carry trade return. Fong et al.[2010] investigates the liquidity and credit risk of the carry trade with a similar sample dataset. And other economists use either India or China market to explain the NDF carry trade [2]. This paper built a dataset that includes both onshore and offshore forward to implement my empirical research.

For the other thing, this paper sheds light to carry trade investors, e.g., multinational firms and banks and hedge funds who use the NDF and DF markets to prevent exchange rate risk or arbitrage. The pricing of NDF contracts could be a proxy for the interest rate of the country with capital control. And the offshore NDF market entered freely without any currency

[2]Burnside et al. [2011] finds that volatility and skewness (or crash risk) factors have explanatory power of the carry trade return. Fong et al.[2010] investigates the liquidity and credit risk of the carry trade with a similar sample dataset. And other economists use either India or China market to explain the NDF carry trade

convertibility restrictions. Furthermore, since the NDF markets have stayed outside the regulatory intervention of the local monetary authorities, the differences of carry trade performance between offshore NDF and onshore DF of one currency contain relevant information, such as market segmentation and supply/demand condition. Therefore, studying the NDF and DF performance is of interest to the carry trade investors.

This paper is enlightened by Doukas and Zhang [2013] that the authors compare the performance of carry trade strategies for currencies with NDF contracts of emerging countries to developed and emerging DF contracts. My work improves and extends theirs in three ways. First, Doukas and Zhang [2013] try to explain the capital control effect to carry trade return. However, they compare DF of developed and emerging currencies with NDF currencies, which lacks the currency fixed effect. While this paper employs the Asian emerging currencies that have both offshore NDF and onshore DF markets to investigate the capital control effect of the same country. This comparison would clearly explain the capital control effect across the regulatory exchange boundary. Second, Doukas and Zhang [2013] use forward with a one-week duration. This paper extends the maturity to 1, 3, and 6 months which are used broadly by investors. The finding would shed light on a carry trade strategy comparison by durations. Third, this paper explains the risk factors of the difference between DF and NDF forward strategy returns.

The main result of this study is that the performance of carry trade with 1 month forward is better than longer maturities based on the Sharpe ratio indicator. Among different markets, onshore DF strategy performs better than offshore NDF as a hedge choice on the whole sample period, especially the financial crisis. The CID has a significant positive effect on carry trade returns, and the influence is even substantial in DF carry trade strategies. This finding indicates that the onshore market has stricter capital control than the offshore NDF market, so this gives an excess return to the DF forward carry trade strategy. Multivariate regression results show that besides convertibility risk, the alternative risk factors such as liquidity risk, FX volatility risk, and currency crash risk do not have significant persistent effects on carry trade returns. Only the funding market liquidity can partially influence the carry trade return negatively. However, the alternative risk factors can explain the deviation of DF and NDF markets. The funding market liquidity and currency crash risk have a positive effect on the excess return of DF carry trade. Contemporaneous, the FX volatility has a negative impact on the excess return of DF carry trade.

The structure of the paper is as follows. The next chapter reviews several related works of literature. Chapter 3 introduces the background of NDF and DF markets. Chapter 4 presents the empirical model. Chapter 5 introduces my database. Chapter 6 reports the results of the analysis. Chapter 7 concludes the results.

Chapter 2

Literature Review

The empirical test of UIP and carry trade returns show mixed results. Using pooled time-series, Bansal and Dahlquist [2000], Flood and Rose [2002] and Frankel and Poonawala [2010] present that carry trades based on the developed currencies are more profitable than the developing currencies. However, these findings consider one dimension of the carry trade return; several pieces of literature use the asset pricing model, including the risk premium to measure the excess return of the carry trade and get opposite results. With a sample including more emerging currencies, Burnside, Eichenbaum, and Rebelo [2007] report that carry-based, actively-managed portfolios performed surplus return by a broad cross-section of currencies including developed and emerging economies. Markwat, Van Dijk, Swinkels, and De Zwart [2008] and Gilmore and Hayashi [2011] proved Burnside, Eichenbaum, and Rebelo [2007] with different countries and periods. However, a recent study by Hassan and Mano [2014] casts doubts on some of the preceding explanations. Using a broad set of currencies over a long period, they reject the hypothesis that high-interest-rate currencies tend to appreciate relative to low-interest-rate currencies.

The UIP carry trade literature assumes that CIP holds. However, that is not true. Aliber [1973] finds that political risk associated with prospective capital controls can lead to deviations from covered interest rate parity. Several economists prove his notion. Obstfeld [1993] calculates onshore-offshore interest rate differentials and finds that deviations from CIP exist for Euro currencies in the mid-1980s when capital controls are in place. Dooley and Isard [1980] report that the existence of capital controls partially explains the deviations from covered interest parity conditions. Kumhof [2001] tests the covered interest parity in three emerging markets. Due to the temporarily adequate capital controls, substantial bank default risk premium, and capital market imperfections, the CIP differentials and volatilities increased dramatically during the Asian crisis. Batten and Szilagyi [2006] find that CIP deviations have mainly been eliminated by 2000 using daily time series data for the USD/JPY forward market. Besides these study on carry trades and CIP deviations, the studies on carry trade return through forwards is scarce before 2008 due to the incompleteness of forward markets in emerging countries. During the great depression, most of the UIP carry trade strategy lost tremendously because of the high turbulence of the financial market. Then some economists start to investigate the short-term CIP deviations between the US dollar and major currencies and the effects of the Federal Reserve responses to the crisis on credit and liquidity risk (Baba and Packer [2009] , Hui, Genberg, and Chung [2011] and McAndrews and Sarkar [2009]). Skinner and Mason [2011] find that the aspect of credit risk, not transaction costs or the size of the economy, is the source of violations in CIP in the long-term capital markets.

Most of CIP carry trade studies focus on Asian emerging markets. George and Mallik [2009] find that the forward premia appear to be more strongly influenced by current account transactions than by capital flows in India. Because China has both onshore and offshore FX market and money market, Funke, Shu, Cheng, and Eraslan [2015] use extended GARCH models to explore the character of fundamentals, global factors, and policies related to renminbi internationalization in determining the divergence between the onshore and offshore exchange rates. They find that cross-border renminbi outflows have a particularly discernible impact in reducing the volatility of the pricing gap between these two markets. Using a GMGARCH-MSKST model, Wang et al. [2014] analyze return and risk interactions among spot, NDF, and DF exchange rates for Korea and Taiwan. They conclude that the liberal currency market policies of Korea stimulate market integration. Besides these time-series research, Doukas and Zhang [2013] investigate the performance of carry trade strategies for currencies with non-deliverable forward contracts, based on the panel dataset with 64 countries. They find that carry trades for currencies with NDF contracts have higher Sharpe ratios compared to DF carry trades in developing countries.

Chapter 3

Non-Deliverable Forward and Deliverable Forward Market

Non-deliverable forwards (NDF) are foreign exchange derivative products traded over the counter. Investors of the NDF contract settle the transaction, not by delivering the underlying pair of currencies like deliverable forwards. So the NDF is famous for emerging market currencies with capital control restrictions. NDF investors are financially protected from exchange rate fluctuations by the compensating U.S. dollar payment paid or received based upon the NDF fixed rate because of needless to translate into foreign currencies. Without the jurisdiction of countries with convertibility restrictions, NDF trading that developed in offshore financial centers such as Hong Kong and Singapore for Asian currencies, New York, and London mainly traded for Latin American currencies. The market participants of NDFs are (i) multinational firms and international portfolio managers need to hedge their exposure to non-convertible currencies, (ii) speculators who wish to make a profit on the volatile derivatives,

Table 3.1: Global and London NDF Daily turnover

	USD							
Global	BRL	CNY	INR	KRW	RUB	TWD	Other	Total
Net-net	15,894	17,083	17,204	19,565	4,118	8,856	36,790	119,510
Net-gross	19,928	23,696	22,678	29,086	4,975	12,131	45,309	157,803
London	12,315	5,970	10,471	8,735	4,225	...	16,530	58,246
Memo:Oct2013	8,141	4,453	6,014	6,807	2,291	...	13,794	41,500

* Note: this table reports NDF daily turnover in millions of US dollars on April 2013. BRL = Brazilian real; CNY = Chinese renminbi; EUR = euro; INR = Indian rupee; JPY = Japanese yen; KRW = Korean won; RUB = Russian rouble; TWD = New Taiwan dollar; USD = US dollar.
Sources: Bank of England; Triennial Central Bank Survey.

(iii) major financial institutions as market makers provide the liquidity. Table 3.1 and 3.2 from Mccauley [2014] show the daily turnover of NDFs.

The latest Triennial Survey reported $120 billion in daily NDF turnover in the US dollar. This amount represented 19% of all forward trading globally and 2.4% of all currency turnovers. Almost two-thirds traded in six major currencies against the dollar. Like emerging market currencies, 94% share of NDF tradings is quoted against the dollar. In all exchange forward trading volume, offshore NDF weighs 68%, which is higher than onshore deliverable forward. NDF turnover proliferated since 2013, in line with emerging market turnover in general (Ma et al. [2004], Rime and Schrimpf [2013]). BIS surveys the global forward market from April 2008 to April 2013 and concludes that the NDF market developed faster than the forward market or the foreign exchange market as a whole. During those five years, the share of NDF turnover of forwards grew from 12% to 23%. It is evident that NDF trades have increased: the turnover in Asian NDFs is at least ten times estimates of their turnover from 2000 (Ma et al. [2004], Kim and Song [2010]). Though the DF contains 12.8% of all forwards turnover, it still has a significant amount of 15 million US$ volume. The investors could discover the carry trade opportunities on DF markets with higher liquidity risk than NDF markets. Figure 3.1 shows the

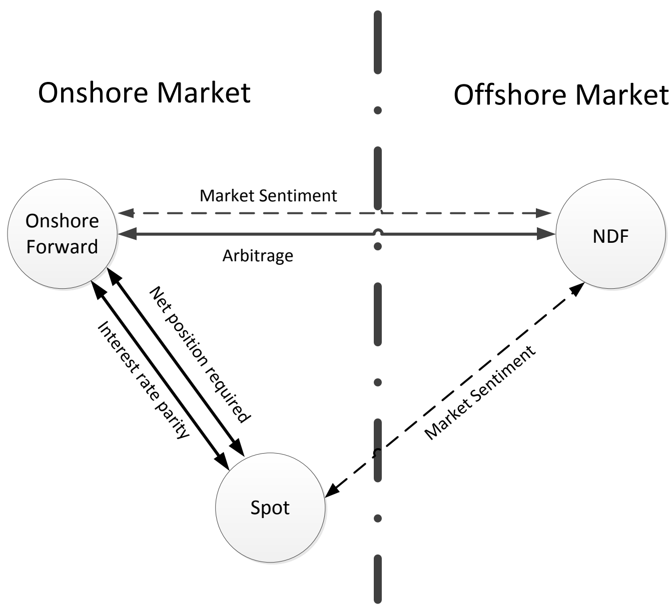
Table 3.2: Global and London NDF Daily turnover

Six currencies	DFs	NDFs	Total	Memo%	DFs	NDFs	Total
Onshore	10,138	4,550	14,688	Onshore	8.9%	4.0%	12.8%
Offshore	21,543	78,170	99,713	Offshore	18.8%	68.3%	87.2%
Total	31,680	82,720	114,401	Total	27.7%	72.3%	100.0%
BRL	DFs	NDFs	Total	CNY	DFs	NDFs	Total
Onshore	2,709	559	3,268	Onshore	2,441	...	2,441
Offshore	6,908	15,335	22,243	Offshore	7,102	17,083	24,185
Total	9,617	15,894	25,511	Total	9,543	17,083	26,626
INR	DFs	NDFs	Total	KRW	DFs	NDFs	Total
Onshore	3,140		3,140	Onshore	1,118	3,538	4,656
Offshore	1,879	17,204	19,083	Offshore	1,410	16,027	17,437
Total	5,019	17,204	22,223	Total	2,528	19,565	22,094
RUB	DFs	NDFs	Total	NTD	DFs	NDFs	Total
Onshore	512	231	743	Onshore	218	222	440
Offshore	3,187	3,887	7,074	Offshore	1,057	8,634	9,691
Total	3,699	4,118	7,817	Total	1,274	8,856	10,130

* Note: DFs = deliverable forwards; NDFs = non-deliverable forwards. Data is reported on a net-net basis, ie adjusted for local and cross-border inter-dealer double-counting.
Sources: Bank of England; Triennial Central Bank Survey.

trading linkages between onshore and offshore markets. The vertical dot-dash line represents the FX transaction boundary. All of these seven Asian countries have different kinds of capital controls. In the de jure measure of financial openness Chinn-Ito index, they all ranked after 63 (Korea), which means highly closed financial accounts. Since they have both NDF and DF markets and capital controls, this paper investigates the effect of capital control on the carry trade returns through the data from these countries.

Figure 3.1: Linkages Between Onshore Offshore Markets



Chapter 4

Methodology

4.1 The returns of DF and NDF carry trades

This paper measures the carry trade return of DF and NDF carry trades based on the strategies developed by Burnside et al. [2006] by selling forward currencies that have a forward premium and purchasing forward currencies that have a forward discount. The spot and forward exchange rates are quoted in US dollars. Moreover, the decision rule is as follows:

$$x_t = \begin{cases} +1, & \text{if } F_t^b/S_t^a > 1 \\ -1, & \text{if } F_t^a/S_t^b < 1 \\ 0, & \text{otherwise} \end{cases} \tag{4.1}$$

where F_t^b and F_t^a denote the bid and ask forward exchange rates at time t. Furthermore, x_t defines the position of the carry trade.

The realised return, z_{t+n}^{DF}, is calculated for DF carry trade as follows:

$$z_{t+n}^{DF} = \begin{cases} x_t(F_t^b/S_{t+n}^a - 1), & \text{if } x_t > 0 \\ x_t(F_t^a/S_{t+n}^b - 1), & \text{if } x_t < 0 \\ 0, & \text{otherwise} \end{cases} \tag{4.2}$$

where S_{t+n}^b and S_{t+n}^a denote the bid and ask spot exchange rates at the maturity of the forward contract and n is the number of days to the forward contract.

For NDF carry trade, Eq.(4.2) includes the fixing rate on the valuation day. The realized return, z_{t+n}^{NDF}, is calculated as follows:

$$z_{t+n}^{NDF} = \begin{cases} x_t(F_t^b/S_V^{FIX} - 1), & \text{if } x_t > 0 \\ x_t(F_t^a/S_V^{FIX} - 1), & \text{if } x_t < 0 \\ 0, & \text{otherwise} \end{cases} \tag{4.3}$$

where S_V^{FIX} denotes the fixing rate for an NDF contract on the valuation day; n refers to the number of days to the settlement day; V is the actual number of days to the different currency contracts.

4.2 Factors of carry trade returns

In order to test whether the carry trade returns are related to deviations from covered interest parity, a modified CIP equation as follows:

$$z_{t+n}^{k} \approx i_{k,t} - i_{k,t}^{*} - \triangle s_{t+n}^{k} \tag{4.4}$$

where z_{t+n}^{k} denotes the carry trade return on transaction k defined in Eqs.(4.2) and (4.3), $i_{k,t}$ is the bid (or ask) target interest rate, $i_{k,t}^{*}$ is the ask (or bid) U.S. interest rate, $\triangle s_{t+n}^{k} = s_{t+n}^{k} - s_{t}^{k}$, by taking log to all these variables. The left-hand side of Eq.(4.4) is the carry trade return using the previous calculation. The right-hand side of Eq.(4.4) is the return of carry trades by holding a long(short) position in high-yielding (low-yielding) currency and a short (long) position in U.S. dollars. Although the two strategies are operationally different, the excess returns should be approximately equal under the condition of CIP.

Based on Frankel [1992], this paper decomposes the interest rate differential $i_{k,t} - i_{k,t}^{*}$ as follows:

$$i_{k,t} - i_{k,t}^{*} \equiv \left[i_{k,t} - i_{k,t}^{*} - (f_{k,t} - s_{k,t})\right] + \left(f_{k,t} - s_{k,t+n}^{e}\right) + \triangle s_{k,t+n}^{e} \tag{4.5}$$

where $f_{k,t}$ denotes the forward exchange rate, $s_{k,t+n}^{e}$ denotes the expected bid or ask spot rate for time $t+n$ and $\triangle s_{k,t+n}^{e} = s_{k,t+n}^{e} - s_{k,t+n}$ is the expected difference of spot rate from time t to $t+n$. Substituting Eq.(4.5) into Eq.(4.4), carry trade returns can be explained in three factors:

$$z^k_{t+n} \approx \left[i_{k,t} - i^*_{k,t} - (f_{k,t} - s_{k,t})\right] + \left(f_{k,t} - s^e_{k,t+n}\right) + \left(\triangle s^e_{k,t+n} - \triangle s_{k,t+n}\right) \tag{4.6}$$

In this equation, the first term is the "covered interest differential" or "political risk premium" for carry trade transaction k measured at time t when the trade is realized:

$$CID_{k,t} = \left[i_{k,t} - i^*_{k,t} - (f_{k,t} - s_{k,t})\right] \tag{4.7}$$

CID reflects the risk premium across countries, such as capital controls, transaction costs, default risk, and the expectation of future uncertainty. This paper uses NDF currencies CID as a risk factor capturing the currency convertibility restrictions and capital controls. According to Frankel [1992], a positive CID suggests capital inflows to the home country and controls on capital inflow while a negative CID indicates capital outflows from the home country and controls on the capital outflow. Otherwise, the CID equals zero, which implies that covered interest parity holds. Frankel [1992] test The concept of CID as a risk factor. They measure the performance of carry trade strategies with CID for 53 currencies, especially those emerging markets with NDF contracts. Since the convertibility restrictions and capital controls are in effect, the CID from DF should be positive (negative) during the financial crisis period (2008) because of the surging future capital controls on capital inflows(outflows). Moreover, CID from NDF should be less than DF. Finally, the carry trade returns should be related to CIDs.

The empirical study follows the carry trade literature by using alternative risk factors such as FX volatility, global FX liquidity, and other fundamentals. This paper tests whether carry trade returns are in response to deviations from covered interest parity by estimating the following panel regression:

$$z^k_{t+n} = \alpha + \beta * CID_{k,t} + \varepsilon_{k,t} \tag{4.8}$$

where z^k_{t+n} is the carry trade return on transaction k defined in Eqs.(4.2) and (4.3), $CID_{k,t}$ is the covered interest differential defined in Eq.(4.7). α is the intercept, β is the estimated coefficient and $\varepsilon_{k,t}$ is the residual. The null hypothesis of $\alpha = 0$ and $\beta = 0$ states that the carry trade cannot make a profit after controlling for $CID_{k,t}$, furthermore, covered interest parity holds. The alternative hypothesis of $\alpha \neq 0$ indicates that the carry trade return exists after controlling for $CID_{k,t}$, and $\beta \neq 0$ indicates that covered interest parity does not hold and $CID_{k,t}$ is related to the carry trade returns. Eq.(4.8) estimates for both DF and NDF carry trades.

Furthermore, the return of carry trade is feasiblly influenced by the financial risk factors, so the model includes several risk factors and fundementals to explain the determinants of carry trade. The multifactor model is :

$$z^k_{t+n} = \alpha + \beta * CID_{k,t} + \sum_{j=1}^{N} \eta_j * RKF^j_{k,t} + \sum_{j=1}^{N} \gamma_j * RKF^j_{k,t+n} + \varphi_{k,t} \tag{4.9}$$

where $RKF^j_{k,t}$ denotes the risk factor j for carry trade transaction k measured at time t when the trade is entered, $RKF^j_{k,t+n}$ denotes the risk factor j for carry trade transaction k measured at time $t+n$ when the trade is closed, N is the number of risk factors, $\varphi_{k,t}$ is the residual, and other variables are defined previously. If β, η_j and γ_j are significant, the result shows that carry trade returns are related to deviations from covered interest parity and other risk factors. The estimates of alternative risk factors are defined as follows.

4.2.1 Volatility proxy

Following Menkhoff et al. [2012], this paper estimates FX volatility ($FXVOL_t$) by calculating the daily absolute log-returns of spot exchange rates, $|r_{m,t}| = |\triangle s_{m,t}|$, for each currency m in my sample on day t and then averaging all currencies available on day t. This paper obtains the weekly FX volatility when $T = 5$ trading days:

$$FXVOL_t = \frac{1}{T}\sum_{t=1}^{T}\left[\sum_{m=1}^{M}\frac{|r_{m,t}|}{M}\right] \tag{4.10}$$

where M is the number of currencies on day t, and T is the number of trading days. This regression analysis focuses on weekly volatility innovations by taking the first difference of the FX volatility series, following Ang et al. [2006].

4.2.2 Liquidity proxies

Following Menkhoff et al. [2012], this paper employs the FX bid-ask spread as my liquidity measure for the FX market. The FX bid-ask spread ($SPREAD_t$) calculation uses the same aggregating scheme as FX volatility in Eq.(4.10):

$$SPREAD_t = \frac{1}{T}\sum_{t=1}^{T}\left[\sum_{m=1}^{M}\frac{|SPREAD_{m,t}|}{M}\right] \tag{4.11}$$

where $(SPREAD_t)$ is the percentage bid-ask spread in the spot rate for currency m on day t. The larger is $(SPREAD_t)$, the weaker power of liquidity in the FX markets. The current FX bid-ask spread is included in the regression analysis.

On the funding side, the TED spread is a proxy to measure the carry trade liquidity of U.S.(Brunnermeier and Pedersen [2009]). The TED_t spread is

$$TED_t = i_t^{EUD} - i_t^{TBill} \tag{4.12}$$

where i_t^{EUD} is a 3-month LIBOR and i_t^{TBill} is 3-month U.S. Treasury bill rate. A higher TED_t spread represents illiquidity in the funding market (U.S. money market) for carry trades.

4.2.3 Skewness proxies

The absolute realized skewness measures the crash risk, following Brunnermeier and Pedersen [2009]:

$$SKEW_{m,t} = \left| \frac{\frac{1}{T}\sum_{t=1}^{T}\left(r_{m,t} - \bar{r_{m,t}}\right)^3}{\left[\frac{1}{T}\left(r_{m,t} - \bar{r_{m,t}}\right)^2\right]^{3/2}} \right| \tag{4.13}$$

where $\bar{r_{m,t}}$ is the mean return of log spot rates for currency m on day t and $T = 5$ trading days in a week.

4.3 The difference between DF and NDF carry trades

From Figure 3.1, the significant difference between DF and NDF carry trade is that the investors need to enter the onshore market with capital controls. The offshore NDF market does not have convertibility risk due to the forward is issued in dollars so that the investor can freely enter and exercise the NDF contract conditioning on Eq.(4.1). However, the onshore forwards are issued in home currencies. The investors need to translate dollars to those currencies which have capital controls or convertible restrictions. Eq.(4.8) tests the deviation between DF and NDF return by estimating the following panel regression:

$$\Delta z_{t+n}^{k} = \alpha_d + \beta_d * \Delta CID_{k,t} + \phi_{k,t}$$

$$\Delta CID_{k,t} = \left[i_{k,t} - i_{k,t}^{*} - \left(f_{k,t}^{df} - s_{k,t}\right)\right] - \left[i_{k,t} - i_{k,t}^{*} - \left(f_{k,t}^{ndf} - s_{k,t}\right)\right] = f_{k,t}^{df} - f_{k,t}^{ndf}$$

$$\Delta z_{t+n}^{k} = \alpha_d + \beta_d * \left(f_{k,t}^{df} - f_{k,t}^{ndf}\right) + \phi_{k,t} \tag{4.14}$$

where Δz_{t+n}^{k} is the deviation between DF and NDF carry trade return on transaction k, this paper decomposes $\Delta CID_{k,t}$ into the forward deviation $f_{k,t}^{df} - f_{k,t}^{ndf}$ where the forward deviation explains the currency conversion estimate. α_d is the intercept, β_d is the estimated coefficient, and $\phi_{k,t}$ is the residual. The null hypothesis of $\alpha_d = 0$ and $\beta_d = 0$ states that carry trade returns are equal on either forward market after controlling for $\Delta CID_{k,t}$. The alternative hypothesis of $\alpha \neq 0$ indicates that excess carry trade return exists after controlling for $\Delta CID_{k,t}$, and $\beta \neq 0$ indicates $\Delta CID_{k,t}$ is related to the excess carry trade returns.

Additionally, the minor difference between DF and NDF carry trade is the market segmentations e.g., market liquidity, the participations, etc.. Those alternative risk factors would explain the deviation. Based on Eq.(4.9)[1], the multifactor model estimates:

$$\Delta z_{t+n}^{k} = \alpha_d + \beta_d * \left(f_{k,t}^{df} - f_{k,t}^{ndf}\right) + \sum_{j=1}^{N} \eta_j * RKF_{k,t}^{j} + \sum_{j=1}^{N} \gamma_j * RKF_{k,t+n}^{j} + \theta_{k,t} \tag{4.15}$$

[1]The notations of terms are the same as Eq.(4.9).

Chapter 5

Data

The total sample consists of exchange rates for seven countries, quoted against the U.S. dollar, including China, India, Korea, Malaysia, the Philippines, Vietnam, and Taiwan. The daily spot exchange rates and offshore NDF rates are from WM/Reuters. The onshore DF rates are from Bloomberg. This paper uses the forward with three different terms: 1 month, 3 month, and 6 month to simulate carry trade strategies. The total sample length is from September 2002 to June 2016. However, the DF rates are available from 18 June 2007 for China; the NDF rates are available for China, Malaysia, and Vietnam from 2 August 2004, 14 September 2004, and 28 March 2007, respectively.

Following Burnside et al. [2006], this paper constructs the weekly data set by sampling the daily data on every Wednesday when it meets the trade condition, Eq.(4.1). The data contains both bid and ask exchange and forward rates. The ask (bid) rates are the rate at which a trader in the inter-dealer market can buy (sell) U.S. dollars or forwards from a currency or forward dealer. Each trade occurs following the condition of Eq(4.1). Eqs. (4.2) and (4.3) currencies calculate the carry trade returns for DF and NDF respectively. All foreign exchange rates are quoted by U.S. dollar. Following the Indicative Survey Rate Methodology that published by the EMTA for determining NDF fixing rates, the midpoint of the close bid-ask spot exchange rates on the valuation day for an NDF contract is used to calculate the NDF carry trade returns.

A 1-month interbank repurchase rate for foreign interest rates (i) and 1-month London Interbank Offered Rate (LIBOR) for the United States (i^*) are the interest rate in calculation. If countries do not have enough data, the 1-month deposit rate is a good proxy. The CID_k^t is calculated by matching each carry trade transaction with its forward premium and interest rate differential. Because the LIBOR fixed closed after the Asian markets, the previous business day LIBOR is used to compute the interest rate differentials for all Asian currencies (Kumhof [2001]). TED is the difference between the 3-month Eurodollar interbank deposit rate and the 3-month U.S. Treasury bill rate.

Chapter 6

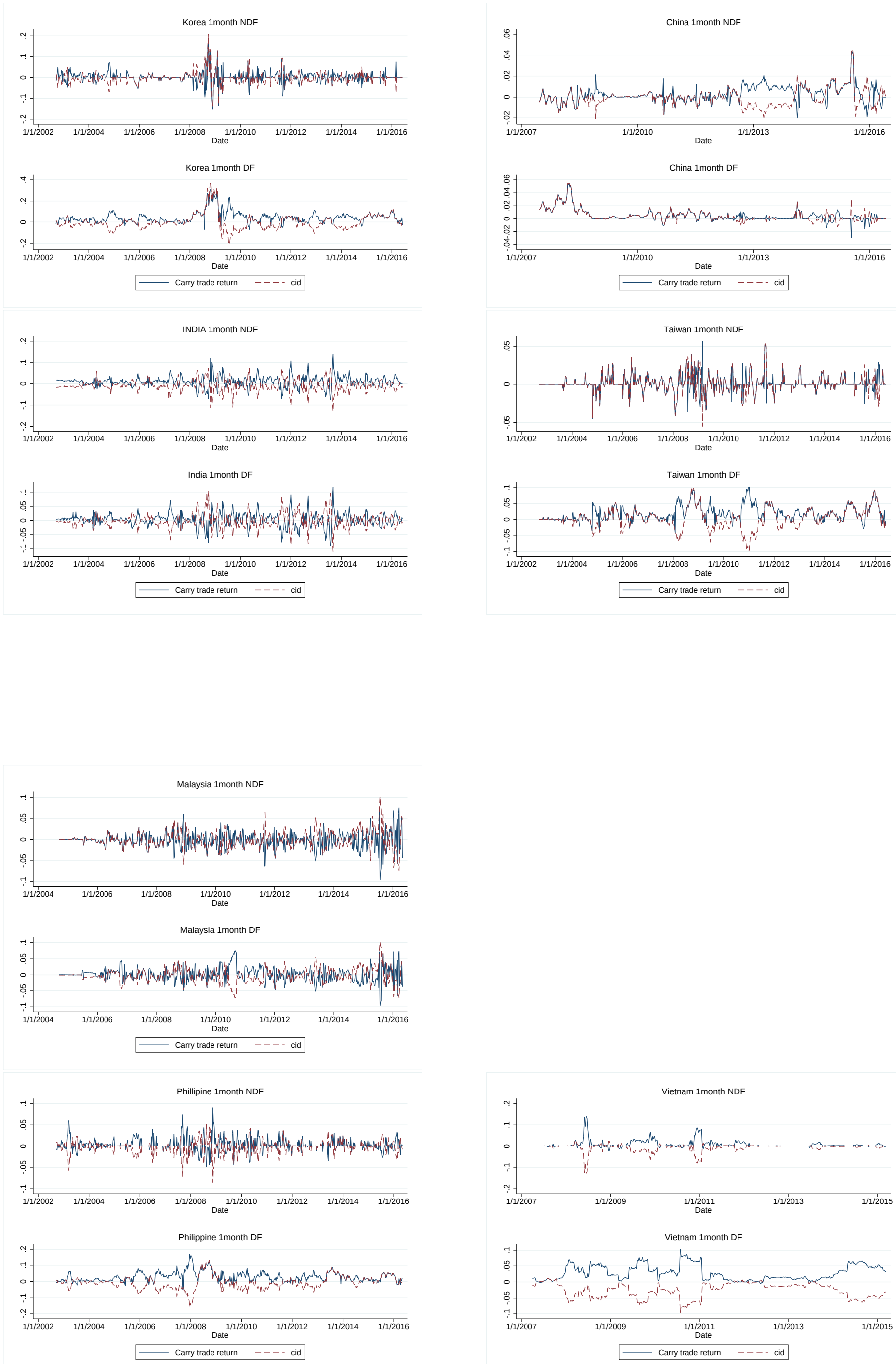
Empirical Results

Figure 6.1 describes the movement of carry trade return and CID for 1-month forwards in the seven Asian countries. The finding is that the carry trade return and CID move to opposite directions during the non-crisis period; however, in the crisis period, their movements are overlapped. Another fact is that the volatility increases in the crisis period, and DF fluctuates more severely than NDF markets. This section will analyze the sample with statistical methods to test the observations.

6.1 NDF and DF carry trade returns

Panel A of Table 6.1 describes the summary statistics of carry trade returns with the mean, standard deviation, skewness, kurtosis, and Sharpe ratios for the entire sample 09/2002-06/2016 in the first column. Because the data is not normally distributed based on the Shapiro-Wilk test, this paper implements the univariate t-tests on the null hypothesis that the mean of

Figure 6.1: Carry trade return and CID movement



carry trade returns is equal to zero. This paper applies the univariate z-tests on the null hypothesis that the Sharpe ratios are equal to zero based on Opdyke [2007], which is derived without the assumption of normal distribution. The mean return for the NDF sample is 0.476 % weekly and statistically significant at the 0.01 level. The mean return for the DF sample is 2.374 %, which is much higher than NDF return. This finding supports the risk premium on the onshore side. Based on the higher risk premium, the standard deviation of DF return, at 0.050, is higher than NDF at 0.042. However, the DF performance has a higher Sharpe ratio at 0.473, followed by NDF at 0.112. In the subsamples, this paper shows 1 month, 3 month and 6 month forward to test the sensitivity of carry trade returns by different forward maturities. On the NDF side, 6 month return is the highest followed by 1 month and 3 month. With the increasing of forward maturity, the standard deviation raises from 0.021 to 0.053. So the Sharpe ratio reports that 1 month NDF trade is safer than long maturity trades. On the DF side, both returns and standard deviations increase monotonically by maturities; however, the 1 month carry trade has the highest Sharpe ratio. Test 1 in Panel C of Table 3 reports the equality tests on the null hypotheses of equal means and equal variances between the two sub-samples. The results show that an ANOVA F-test can reject the null hypothesis of equal means at the 0.01 level, while a Bartlett test rejects the null hypothesis of equal variances at the 0.01 level, confirming the differential performance of carry trades between NDF and DF currencies during the entire sample period.

As mentioned above, carry trades suffer substantial losses due to sudden shocks like currency crashes and financial market collapse. In order to test the sensitivity of the sample, the whole data set splits around the 2008 U.S. financial crisis. The crisis period is from May

Table 6.1: NDF and DF carry trade returns

Panel A: Summary statistics for the entire sample period and subsample periods by cirsis

	Total Sample		1month		3month		6month	
	NDF	DF	NDF	DF	NDF	DF	NDF	DF
Mean	0.476^{***}	2.374^{***}	0.386^{***}	1.924^{***}	0.344^{***}	2.447^{***}	0.704^{***}	2.761^{***}
Std. Dev.	0.042	0.050	0.021	0.036	0.046	0.053	0.053	0.058
Kuotosis	19.269	12.189	79.578	23.834	24.189	14.647	7.486	6.340
Skewness	0.665	1.427	4.001	3.033	1.686	1.633	-0.468	0.626
#OBS	12777	12777	4301	4301	4278	4278	4198	4198
Sharpe ratio	0.112^{***}	0.473^{***}	0.181^{***}	0.534^{***}	0.074^{***}	0.461^{***}	0.133^{***}	0.472^{***}

Panel B: summary statistics for crisis and non-crisis periods

	Crisis Period 8/2007-3/2009					
	1month NDF	1month DF	3month NDF	3month DF	6month NDF	6month DF
Mean	0.266^{***}	3.506^{***}	-0.062^{***}	3.646^{***}	-0.133^{***}	3.044^{***}
Std. Dev.	0.0313	0.0582	0.0662	0.0789	0.0887	0.0948
Kuotosis	11.7366	8.7316	9.1852	5.4319	4.8026	4.3662
Skewness	0.6780	2.0589	0.8406	1.0242	-0.0542	0.8443
#OBS	564	564	567	567	567	567
Sharpe ratio	0.0849^{***}	0.6025^{***}	-0.0093^{***}	0.4619^{***}	-0.0150^{***}	0.3212^{***}

	Non Crisis Period 9/2002-6/2016					
	1month NDF	1month DF	3month NDF	3month DF	6month NDF	6month DF
Mean	0.404^{***}	1.686^{***}	0.404^{***}	2.266^{***}	0.834^{***}	2.717^{***}
Std. Dev.	0.0194	0.0307	0.0426	0.0478	0.0444	0.0505
Kuotosis	122.0115	30.8375	31.1331	19.0255	5.1522	4.5407
Skewness	5.7436	2.9176	2.0922	1.6873	-0.5738	0.1878
#OBS	3737	3737	3711	3711	3731	3731
Sharpe ratio	0.2085^{***}	0.5499^{***}	0.0949^{***}	0.4741^{***}	0.1878^{***}	0.5379^{***}

Panel C:Equality tests across DF and NDF fro the entire sample and subsample periods

	Test 1	Test 2	Test 3
ANOVA F-test of equal means	0.0190^{***}(0.000)	0.0167^{***}(0.000)	0.0337^{***}(0.000)
Bartlett test of equal variances	370.3620^{***}(0.000)	308.9515^{***}(0.000)	48.8022^{***}(0.000)

* Note: this table reports the summary statistics for carry trade returns in percentage. Univariate t-tests is performed on the null hypothesis that the means are equal to zero. Univariate z-tests are performed on the null hypothesis that the Sharpe ratios are equal to zero. Equality tests are performed on the null hypotheses of equal means and equal variances across DF and NDF carry trade returns. Test 1 refers to equality tests for the whole period 2002∼2016. Test 2 refers to equality tests for the non-crisis period 2002∼2016, excluding the crisis period. Test 3 refers to equality tests for the crisis period 5/2008∼3/2009. Bartlett tests are adjusted for non-normality. This paper denotes *, **, and *** for significance at 0.10, 0.05 and 0.01 levels, respectively. P-values are in parentheses.

1, 2008, to March 31, 2009, when the great recession spread to the emerging markets on May 1, 2008, and by the end of March 2009, the world financial markets recovered to stable. The non-crisis period for the total sample is from 2002 to 2016, excluding the crisis period.

The top table of Panel B reports the results during the crisis period between NDF and DF currency returns. Carry trades of NDF currencies suffer the most massive losses, with a mean return of 0.266%, -0.062%, and -0.1133% respectively by maturities, which is consistent with Doukas and Zhang [2013]. All the NDF returns on the crisis period are lower than regular time. Although the turmoil shocks the global financial markets, the DF carry trades on crisis period have even higher profits, with a return of 3.506%, 3.646%, and 3.044%. Depending on the volatility, the shorter maturity is, the lower standard deviation for both NDF and DF carry trades. So the Sharpe ratio performs best when using the 1 month forward carry trade strategy. The bottom table of Panel B reports the results of the non-crisis period of the dataset, excluding the crisis period. The features of mean returns are opposite to the crisis period; however, the features of standard deviations are persistent with the crisis period. Thus the 1 month carry trade strategy still has the highest Sharpe ratio for the non-crisis period. The last column of the equality tests in Panel C of Table 3 confirms the differential performance across 1 month, 3 month, 6 month DF and NDF carry trades during the great recession. The null hypotheses of equal mean and equal variances are rejected at the 0.01 level. The second column has the same results for the non-crisis period. Overall, the results present that, during the great recession, the performance of DF carry trade is more stable than NDF carry trade in Asian markets based on the Sharpe ratio indicators.

In summary, this section concludes that the return of carry trade with 1 month forward is higher than 3 month and 6 month in all periods based on the Sharpe ratio indicator. The shorter the maturity, the better carry trade performance. For different markets, onshore DF carry trade performs better than offshore NDF carry trade in Asian markets. During both crisis and non-crisis periods, DF carry trades realize higher Sharpe ratios than NDF.

6.2 Determinants of carry trade returns

Last section investigates the connection between carry trade returns to CID and alternative risk factors. This section tests the conjecture by estimating Eq.(4.8) and (4.9) with panel regressions.

6.2.1 Summary of CID

Table 6.2 presents the statistics of components of $CID_{k,t}$ of the dataset. The first row $i-i^*$ is the interest rate differential between the home country and the U.S. The second row $f-s$ denotes the forward premium for the U.S. dollars. The sample matches with each carry trade transaction k when the trade is entered at time t. The first panel of Table 2 represents that the mean interest rate differential for the entire sample is 0.0540% weekly (2.808% annual). Furthermore, the mean forward premiums are 0.3973% and 0.6457% for NDF and DF, respectively. Then the mean of $CID_{k,t}$ is -0.3433% and -0.5917% weekly for NDF and DF, respectively. The negative sign of $CID_{k,t}$ means the Asian countries control the capital outflows in most periods.

Comparing with NDF, the DF carry trade has a negative $CID_{k,t}$ with larger absolute value. The measurement from onshore forward indicates a stricter capital control and higher transaction cost than offshore forward. With different forward maturities, the higher the order of forward entered in the trade, the larger the forward premium which meets the risk premium theory. These results suggest that covered interest parity does not hold for Asian emerging countries on both NDF and DF markets. The bias to the CIP increases with the growth order of forward maturity.

Table 6.2: Carry trade CID statistics

	Total Sample		1 month		3 month		6 month	
	NDF	DF	NDF	DF	NDF	DF	NDF	DF
$i-i^*$	0.0540	0.0540	0.0540	0.0540	0.0537	0.0537	0.0543	0.0540
$f-s$	0.3973	0.6457	0.3278	0.3632	0.3445	0.5751	0.5233	1.0087
CID	-0.3433	-0.5917	-0.2738	-0.3092	-0.2908	-0.5214	-0.4690	-0.9544
#OBS	12777	12777	4301	4301	4278	4278	4198	4198

	Crisis Period 8/2007-3/2009					
	1month NDF	1month DF	3month NDF	3month DF	6month NDF	6month DF
$i-i^*$	0.0434	0.0434	0.0433	0.0433	0.0434	0.0434
$f-s$	-0.0358	-1.7885	-0.9741	-2.8716	-2.4227	-4.1035
CID	0.0792	1.8319	1.0175	2.9150	2.4661	4.1469
#OBS	564	564	567	567	567	567
	Non Crisis Period					
	1month NDF	1month DF	3month NDF	3month DF	6month NDF	6month DF
$i-i^*$	0.0556	0.0556	0.0553	0.0553	0.0560	0.0560
$f-s$	0.3825	0.6871	0.5427	1.0934	0.9834	1.8070
CID	-0.3269	-0.6315	-0.4875	-1.0381	-0.9273	-1.7509
#OBS	3737	3737	3711	3711	3731	3731

* Note: this table reports the means for CID and its components in percentage. $i-i^*$ denotes the interest differential; $f-s$ denotes the forward premium; $CID_{k,t}$ denotes the covered interest differential for each carry trade transaction k when the trade is entered at time t.

The second and third panels of Table 6.2 divide the whole sample into two sub-samples by crisis period (8/2007-3/2009). The financial crisis had a significant shock to the

CIDs. Firstly, the interest rate differentials shrank in the crisis period from 0.0556% to 0.0434% weekly, which equals 0.5% gap annually for 1 month forward. However, the interest rate differentials are consistent with the forward maturities for both subsamples, which concludes that the emerging markets have the same monetary policy as FED. Secondly, the sign of forward premium opposites in the crisis period from positive to negative, which means the home currency faces an appreciation pressure in the crisis period and a depreciation pressure in the non-crisis period. These forward premium gaps exaggerate with the growth of forward maturities. Across NDF and DF carry trades, the onshore deliverable forwards premium growth even faster than offshore non-deliverable forwards premium. Thus, the crisis shock has a more substantial effect on the onshore forward market than the offshore forward market. Finally, the CIDs impacted by the forward premium and had a sign reversion in the crisis period. In the non-crisis period, the CID is positive. Due to the crisis shock, the CID becomes negative. This sign inversion represents the capital restrict converted from controlling capital outflow to inflow in Asian emerging markets. The trends of CIDs by forwards and maturities are consistent with the forward premium. In summary, the great recession has a significant effect on the deviation from covered interest parity of Asian emerging markets due to the changing of forward premium, but the interest differentials are not affected much by this shock.

6.2.2 CID and carry trade returns

This section investigates the relationship between CID and carry trade return in this section and separate the dataset as a previous analysis by using two regression methods to measure the effects during the crisis period. Through the LR test, the panel fixed effect method is more consistent with the data comparing to the pooled OLS, which is used by Doukas and Zhang [2013]. The heterogeneity and cross-section correlation of the sample are consistent with the model. The results show that the sample has both heterogeneity and cross-section correlation. Thus Driscoll and Kraay (1998) is a consistent estimate method. Table 6.3 reports the fixed effect estimates of the panel dataset by Eq(4.8) and Eq(6.1).

$$z_{t+n}^{k} = \alpha + \beta * CID_{k,t} + \lambda * CRISIS + \gamma * CID_{k,t} * CRISIS + \varepsilon_{k,t} \tag{6.1}$$

where *CRISIS* is a dummy variable with a value of 1 for the crisis period from 5/2008 to 3/2009 and 0 otherwise. The estimated coefficients λ and γ represent the differences between crisis and non-crisis periods, and the rest coefficients represent the same as Eq(4.8).

For 1 month forward, the NDF coefficient β for $CID_{k,t}$ is -0.399, which is significant at the 0.05 level. The within R^2 is 0.166, which means this $CID_{k,t}$ independent variable can explain 16.6% of the change of NDF carry trade return. The F-test is significant at the 0.01 level. However, on the onshore side, both $CID_{k,t}$ coefficient and the F-test are not significant and the within R^2 is 0.003. Considering the crisis effect, the estimate coefficients of Eq(4.14) are -0.549 and -0.355 for NDF and DF $CID_{k,t}$ respectively, which are significant at the 0.05 and 0.01 level. The negative sign of β suggests a positive relationship between carry trade returns and $CID_{k,t}$, which substitute the capital control and currency conversion cost. For instance, the mean for 1 month NDF $CID_{k,t}$ is -0.2738%, so the mean carry trade return for 1 month NDF increases by 0.109%(=-0.2738%*(-0.399)) since the effect of $CID_{k,t}$ controlling other variables constant. Comparing to the 1 month forward, the 3 month and 6 month forwards indicate the similar estimate results. The slight differences are that the coefficients are significant at the 0.01 level except for DF estimates for Eq(4.8). Moreover, the absolute estimate value of coefficients is higher than 1 month. This result is consistent with Doukas and Zhang [2013], in which NDF returns contain a premium for the exchange rate risk due to convertibility restrictions and capital controls.

Eq(6.1) Includes the crisis effect to estimate the dataset. For NDF carry trades, the estimated β coefficient is significant in all maturities, whose values are -0.549, -0.605, and -0.583, respectively. All maturities are significant at the 0.01 level. However, the other explainable coefficients are not significant. Besides, the within R^2s are 0.211, 0.255, and 0.262, respectively with the rise of maturities. Thus the CID has a positive effect on the non-crisis period and the adverse effect on the crisis period for NDF carry trade as explained previously. In contrast to DF carry trade, not only the estimated coefficient β is significant, but the γs which are the coefficients of $CID_{k,t} * CRISIS$ valued 0.798, 0.861 and 0.954 respectively, are significant at the 0.01 level. During the non-crisis period ($CRISIS = 0$), the effect of $CID_{k,t}$ to z^k_{t+n} is only determined by coefficient β. The negative β has a positive effect to carry trade return. While in the crisis period($CRISIS = 1$), the effect of $CID_{k,t}$ to z^k_{t+n} is determined by terms $CID_{k,t}$ and $CID_{k,t} * CRISIS$. The aggregation of β and γ would determine the sign of $CID_{k,t}$ in the crisis period. After calculation, the final coefficients of $CID_{k,t}$ are 0.443, 0.446 and 0.467 respectively by maturities for onshore forward. In Table 6.2, the CID in the crisis period is positive. Thus

Table 6.3: Panel Fixed Effect estimates of carry trade returns and CID

	1month NDF		1month DF	
	Eq(4.8)	Eq(6.1)	Eq(4.8)	Eq(6.1)
β	-0.399**	-0.549***	0.042	-0.355**
	(0.086)	(0.044)	(0.122)	(0.072)
λ		0.000		0.013*
		(0.002)		(0.004)
γ		0.433		0.798***
		(0.192)		(0.131)
α	0.003**	0.002***	0.019***	0.014***
	(0.000)	(0.000)	(0.001)	(0.001)
N	4301	4301	4301	4301
Within R^2	0.166	0.211	0.003	0.293
F-stat	21.516	52.350	0.119	29.400
	3month NDF		**3month DF**	
	Eq(4.8)	Eq(6.1)	Eq(4.8)	Eq(6.1)
β	-0.575***	-0.605***	-0.036	-0.415***
	(0.049)	(0.041)	(0.104)	(0.056)
λ		0.004		0.007
		(0.006)		(0.003)
γ		0.066		0.861***
		(0.128)		(0.103)
α	0.001	0.001	0.024***	0.018***
	(0.001)	(0.001)	(0.002)	(0.002)
N	4278	4278	4278	4278
Within R^2	0.253	0.255	0.002	0.281
F-stat	139.604	77.441	0.118	27.579
	6month NDF		**6month DF**	
	Eq(4.8)	Eq(6.1)	Eq(4.8)	Eq(6.1)
β	-0.526***	-0.583***	-0.099	-0.487***
	(0.046)	(0.044)	(0.092)	(0.046)
λ		0.008		-0.006
		(0.008)		(0.006)
γ		0.104		0.954***
		(0.106)		(0.081)
α	0.005*	0.003*	0.027***	0.018***
	(0.001)	(0.001)	(0.003)	(0.002)
N	4198	4198	4198	4198
Within R^2	0.256	0.262	0.014	0.289
F-stat	131.345	63.519	1.138	53.072

* Note: this table reports the estimated coefficients of Eq.(4.8) and Eq.(6.1). I denote *, **, and *** for significance at 0.10, 0.05 and 0.01 levels, respectively. The standard errors are in parentheses, reported in parenthesis, are fixed-effects (within) estimators (Driscoll and Kraay 1998).

the CID effect for DF carry trade return is positive in both crisis and non-crisis periods, which suggests that the increased capital control would increase the DF carry trade return.

In summary, this section suggests three key findings. First of all, the regression models can estimate the CID effect except for Eq(4.8) for onshore deliverable forward. Secondly, the coefficients β are significantly negative in NDF side, which leads to the positive CID effect to carry trade return on the non-crisis period and opposite on crisis period. Thirdly, the coefficients β and γ are significant on DF side, which indicates the positive CID effect to carry trade return on both non-crisis and crisis periods. The onshore forward market has a higher wall to protect the carry trade than the offshore market. These findings are consistent with the result of Table 6.1.

6.2.3 Multiple regression analysis

This section starts to analyze the determinants of carry trade returns in this section by estimating the fixed effect panel regression of Eq.(4.9). I add determinants such as FX bid-ask spread ($SPREAD_{k,t}$), FX volatilities $FXVOL_{k,t}$, $TED_{k,t}$ and currency skewness $SKEWNESS_{k,t}$. These independent variables match each carry trade transaction k when the trade is executed at time t. Then, it includes the determinants on the settlement day in the regression such as $SPREAD_{k,t+n}$, $FXVOL_{k,t+n}$ and $SKEWNESS_{k,t+n}$, in order to measure the settlement effect on the carry trade return, where $t+n$ is the holding period of each forwards.

Table 6.4: Carry trade returns and determinants

	1monthDF			1monthNDF		
	Full model	Non-Crisis	Crisis	Full model	Non-Crisis	Crisis
$CID_{k,t}$	-0.106	-0.442**	0.429**	-0.384**	-0.446**	-0.168
	(0.125)	(0.082)	(0.085)	(0.087)	(0.110)	(0.181)
$SPREAD_{k,t}$	1.256	1.395*	0.964	0.298	-0.114	1.966*
	(0.570)	(0.498)	(0.524)	(0.254)	(0.212)	(0.683)
$SPREAD_{k,t+n}$	0.026	0.014*	0.506	-0.011*	-0.009	-0.499
	(0.011)	(0.005)	(0.661)	(0.004)	(0.006)	(0.959)
$FXVOL_{k,t}$	-2.278	-2.921	0.358	-0.191	-0.142	-4.403
	(1.881)	(1.407)	(2.890)	(0.581)	(0.597)	(2.503)
$FXVOL_{k,t+n}$	5.150	3.838	-3.614	0.731	0.460	-2.921
	(3.169)	(2.540)	(2.400)	(1.412)	(1.386)	(2.340)
$TED_{k,t}$	0.009**	0.004	0.003	0.001	-0.004	0.003*
	(0.002)	(0.006)	(0.002)	(0.001)	(0.003)	(0.001)
$SKEWNESS_{k,t}$	0.003	0.003	-0.003	-0.001	-0.000	-0.006
	(0.002)	(0.001)	(0.004)	(0.001)	(0.001)	(0.005)
$SKEWNESS_{k,t+n}$	0.000	-0.001	-0.001	-0.001	-0.002	0.001
	(0.002)	(0.001)	(0.004)	(0.001)	(0.001)	(0.004)
α	0.001	0.006	0.023*	0.004	0.006*	0.003
	(0.004)	(0.003)	(0.008)	(0.002)	(0.002)	(0.008)
N	4108	3592	516	4108	3592	516
Within R^2	0.088	0.283	0.337	0.200	0.285	0.063
F-stat	12.243	11.288	14.760	33.159	83.891	4.269

	3monthDF			3monthNDF		
	Full model	Non-Crisis	Crisis	Full model	Non-Crisis	Crisis
$CID_{k,t}$	-0.256	-0.568***	0.349**	-0.743***	-0.809***	-0.702***
	(0.122)	(0.080)	(0.077)	(0.076)	(0.071)	(0.102)
$SPREAD_{k,t}$	4.086**	2.045	2.538**	0.984	0.611	1.552
	(0.978)	(0.877)	(0.677)	(0.863)	(1.060)	(1.298)
$SPREAD_{k,t+n}$	1.936	-0.163	0.378	-0.167	-0.806	1.537
	(1.098)	(0.752)	(0.880)	(0.664)	(0.835)	(1.222)
$FXVOL_{k,t}$	-0.826	-2.080*	5.734	0.487	0.112	-1.005
	(1.011)	(0.668)	(4.342)	(0.586)	(0.580)	(5.234)
$FXVOL_{k,t+n}$	3.940**	3.262*	-4.902	1.911**	1.874**	6.682
	(0.700)	(1.009)	(5.153)	(0.414)	(0.492)	(4.277)
$TED_{k,t}$	0.009*	0.018*	0.004*	0.005	-0.018*	0.012**
	(0.003)	(0.007)	(0.001)	(0.004)	(0.006)	(0.003)
$SKEWNESS_{k,t}$	0.004	0.003	-0.006	-0.003	-0.000	-0.016
	(0.002)	(0.002)	(0.005)	(0.002)	(0.002)	(0.007)
$SKEWNESS_{k,t+n}$	-0.000	-0.000	0.001	-0.004	-0.003	-0.005
	(0.003)	(0.002)	(0.005)	(0.002)	(0.002)	(0.006)
α	-0.010	0.003	0.012	0.001	0.006	-0.016
	(0.005)	(0.004)	(0.012)	(0.004)	(0.004)	(0.017)
N	4136	3604	532	4136	3604	532
Within R^2	0.136	0.407	0.263	0.444	0.526	0.364
F-stat	13.791	18.894	51.225	21.337	19.947	32.882

	6monthDF			6monthNDF		
	Full model	Non-Crisis	Crisis	Full model	Non-Crisis	Crisis
$CID_{k,t}$	-0.135	-0.501***	0.388**	-0.542***	-0.608***	-0.610***
	(0.090)	(0.046)	(0.078)	(0.052)	(0.038)	(0.076)
$SPREAD_{k,t}$	2.568*	1.040	1.591	-0.040	0.359	1.656*
	(0.913)	(0.684)	(0.885)	(0.643)	(0.830)	(0.649)
$SPREAD_{k,t+n}$	0.665	0.537	0.131	0.532	-0.947	2.364
	(0.879)	(0.656)	(0.672)	(0.839)	(0.630)	(1.205)
$FXVOL_{k,t}$	-0.456	-1.689*	2.835	0.029	-0.443	-0.771
	(0.906)	(0.558)	(3.904)	(0.439)	(0.390)	(4.339)
$FXVOL_{k,t+n}$	4.418	-0.413	8.897	2.761	0.454	9.164
	(2.447)	(1.352)	(4.431)	(1.743)	(0.990)	(5.555)
$TED_{k,t}$	0.007	0.009	0.001	0.008	-0.020*	0.012**
	(0.004)	(0.008)	(0.002)	(0.005)	(0.006)	(0.003)
$SKEWNESS_{k,t}$	0.005	0.005*	-0.015	-0.003	0.002	-0.035*
	(0.002)	(0.002)	(0.007)	(0.003)	(0.002)	(0.010)
$SKEWNESS_{k,t+n}$	0.003	-0.001	0.005	-0.006*	-0.005	-0.015
	(0.003)	(0.002)	(0.005)	(0.002)	(0.002)	(0.007)
α	-0.004	0.006	0.027	0.009	0.018*	0.010
	(0.007)	(0.006)	(0.013)	(0.006)	(0.005)	(0.016)
N	3984	3466	518	3984	3466	518
Within R^2	0.052	0.314	0.259	0.282	0.311	0.353
F-stat	7.387	18.678	73.351	35.202	54.097	64.258

* Note: this table reports the estimated coefficients of Eq.(4.9). This paper denotes *, **, and *** for significance at 0.10, 0.05 and 0.01 levels, respectively. The standard errors, reported in parenthesis, are fixed-effects (within) estimators (Driscoll and Kraay 1998).

Table 6.4 presents the determinants of carry trade returns using 1 month forwards, 3 month forwards, and 6 month forwards (both onshore and offshore) in three panels respectively weekly. In each panel, the left column reports the model with the whole period, the middle for the non-crisis period and the right for crisis period. As estimated by the 1 month forward, the NDF result suggests that $CID_{k,t}$ is -0.384 and -0.446, which are significant at the 0.05 level for the full sample and non-crisis period, respectively. This finding is consistent with Table 6.3. Determinants of the NDF carry trade are not significant except $SPREAD_{k,t+n}$ in the full model, $SPREAD_{k,t}$ and $TED_{k,t}$ in the crisis period are significant at the 0.1 level. On the other hand, the DF result shows that $CID_{k,t}$ is significant at the 0.05 level in non-crisis and crisis periods whose values are close to Table 6.2. However, determinants are not significant except for $TED_{k,t}$ in the full sample at the 0.05 level and both $SPREAD_{k,t}$ and $SPREAD_{k,t+n}$ in the non-crisis period are significant at the 0.1 level. These findings are consistent with Doukas and Zhang [2013] for developed countries. The conclusion is that most of the determinants do not affect carry trade returns, especially the currency skewness which proxies the crash risk. So is the FX spread which proxies the volatility risk. The currency liquidity has an impact on the carry trade return, which suggests that the larger bid-ask spread, the higher DF carry trade return is in the non-crisis period. With the forward maturity expansion , the second and third panel present similar results on carry trade determinants. For 3 month forward, spread at executed time t is significant at the 0.05 level in the full sample and crisis period but not the settlement time $t+k$. The $FXVOL_{k,t+n}$ is significant in the full sample and non-crisis time for DF and NDF, while $FXVOL_{k,t}$ is only significant at the non-crisis time for DF. $TED_{k,t}$ is significant at all time except the full sample for NDF. The currency crash proxy is still insignificant in 3 month forward. Through the 3 month and 6 month forwards estimation, this paper concludes that the currency risk does not affect carry trade returns. Liquidity measurement affects the executed date. Besides, the currency volatility proxy affects on the settlement time. Overall, this section confirms that $CID_{k,t}$ significantly influences NDF and DF carry trade returns. However, the alternative risk factors such as FX crash risk, funding market risk, FX liquidity, and volatility risk have little effect to carry trade returns.

6.2.4 Endogeneity of CIDs

The previous estimation has treated CID as an exogenous variable in the specification. This section measures possible channels of endogeneity that may bias the estimation and show that they are not possible to dominate the results. The one period lag of independent variable $CID_{k,t-1}$ is predetermined, which is irrelevant to the current error term $\varepsilon_{k,t}$ from Eq.(4.8) and it has a high correlation with $CID_{k,t}$. So $CID_{k,t-1}$ is chosen as the instrument variable for $CID_{k,t}$. This paper implements the Durbin-Wu-Hausman test and weakness IV test.[1] Table 6.5 reports the GMM-IV regression estimates in Eq.(4.8) and (6.1). Comparing Table 6.5 to Table 6.3, the IV estimations corroborate the panel FE findings due to the high first-stage R^2s around 0.90. Besides, the R^2s of estimation in Table 6.5 is greater than those in Table 6.3. The conclusion is that the consistency between the FE and IV estimates supports the findings that CID has a significant positive influence on carry trade returns for both onshore and offshore markets.

[1] See Appendix

Table 6.5: Pannel Fixed Effect GMM estimates with Instrument Variable

	1month NDF		1month DF	
	Eq(8)	Eq(16)	Eq(8)	Eq(16)
β	-0.453***	-0.613***	0.056	-0.334***
	(0.071)	(0.063)	(0.048)	(0.029)
λ		0.001		0.013***
		(0.001)		(0.002)
γ		0.500**		0.766***
		(0.171)		(0.058)
α	0.005***	0.005***	0.030***	0.021***
	(0.001)	(0.001)	(0.002)	(0.001)
N	4261	4261	4261	4261
R-sq	0.197	0.241	0.203	0.428
	3month NDF		3month DF	
	Eq(8)	Eq(16)	Eq(8)	Eq(16)
β	-0.567***	-0.593***	-0.018	-0.393***
	(0.037)	(0.041)	(0.039)	(0.026)
λ		0.005		0.007**
		(0.002)		(0.002)
γ		0.053		0.838***
		(0.086)		(0.063)
α	0.006***	0.005***	0.032***	0.025***
	(0.001)	(0.001)	(0.002)	(0.001)
N	4252	4252	4252	4252
R-sq	0.265	0.267	0.206	0.428

	6month NDF		6month DF	
	Eq(8)	Eq(16)	Eq(8)	Eq(16)
β	-0.523***	-0.576***	-0.097*	-0.476***
	(0.037)	(0.032)	(0.038)	(0.023)
λ		0.009**		-0.006*
		(0.003)		(0.003)
γ		0.092		0.931***
		(0.075)		(0.053)
α	0.010***	0.007***	0.036***	0.029***
	(0.001)	(0.001)	(0.002)	(0.001)
N	4168	4168	4168	4168
R-sq	0.276	0.281	0.210	0.424

* Note: this table reports the estimated coefficients of Eq.(8) and Eq.(16) with predetermined cid instrument variables $CID_{k,t-1}$. This paper denotes *, **, and *** for significance at 0.10, 0.05 and 0.01 levels, respectively. The standard errors, reported in parenthesis, are GMM fixed-effects (within) estimators.

Table 6.6: Deviation of DF and NDF carry trade return

	1 month			
	FE Eq(4.14)	IV Eq(4.14)	FE Eq(6.2)	IV Eq(6.2)
ΔCID	0.103	0.123*	-0.246*	-0.206***
	-0.126	-0.059	-0.082	-0.044
Crisis			0.014	0.013***
			-0.006	-0.002
ΔCID*Crisis			0.685**	0.631***
			-0.153	-0.077
α	0.015***	0.022***	0.012***	0.016***
	-0.001	-0.002	-0.001	-0.002
N	4301	4261	4301	4261
R-sq		0.219		0.357
Within R^2	0.014		0.197	
F-stat	0.672		17.025	

6.2.5 Deviation between NDF and DF carry trade return

Table 6.5 reports the estimated results of Eq(4.14) and Eq(6.2) where Eq(6.2) is similar to Eq(6.1) by Panel FE and IV-GMM regression by 1 month, 3 month and 6 month forward maturity respectively.

$$\Delta z^k_{t+n} = \alpha + \beta * \Delta CID_{k,t} + \lambda * CRISIS + \gamma * \Delta CID_{k,t} * CRISIS + \varepsilon_{k,t} \tag{6.2}$$

The two estimate methods show a similar result that the signs of coefficients are the same. However, the GMM-IV regression reports a more robust estimate than the panel FE estimation with a higher R^2 and confidence intervals. For Eq(4.14), the coefficients of $\Delta CID_{k,t}$ are significant at the 0.1 level, but the sign is positive for 1 month forward and negative for 3 month and 6 month. The reason is that the average deviation of CID is close to zero for 1 month forward so that the estimate for the whole sample is obscure. With the crisis dummy, the

	3 month			
	FE Eq(4.14)	IV Eq(4.14)	FE Eq(6.2)	IV Eq(6.2)
ΔCID	-0.133	-0.123*	-0.437**	-0.420***
	(0.103)	(0.052)	(0.085)	(0.063)
Crisis			0.020*	0.019***
			(0.007)	(0.003)
ΔCID*Crisis			0.608**	0.591***
			(0.144)	(0.089)
α	0.021***	0.018***	0.016***	0.011***
	(0.002)	(0.002)	(0.002)	(0.002)
N	4278	4252	4278	4252
R-sq		0.143		0.229
Within R^2	0.014		0.113	
F-stat	1.681		11.423	
	6 month			
	FE Eq(4.14)	IV Eq(4.14)	FE Eq(6.2)	IV Eq(6.2)
ΔCID	-0.185	-0.152*	-0.509**	-0.411***
	(0.097)	(0.064)	(0.089)	(0.093)
Crisis			0.016	0.015***
			(0.008)	(0.004)
ΔCID*Crisis			0.684**	0.549***
			(0.157)	(0.115)
cons	0.020***	0.018***	0.014***	0.012***
	(0.002)	(0.002)	(0.002)	(0.002)
N	4198	4168	4198	4168
R-sq		0.141		0.199
Within R^2	0.020		0.094	
F-stat	3.635		12.165	

* Note: this table reports the estimated coefficients of Eq.(4.14) and Eq.(6.2) with predetermined instrument variables$\Delta CID_{k,t-1}$. This paper denotes *, **, and *** for significance at0.10, 0.05 and 0.01 levels, respectively. The standard errors are in parentheses, reported in parenthesis, are fixed-effects (within) estimators (Driscoll and Kraay 1998) and GMM respectively.

estimates become more sensitive. The coefficients for Eq(6.2) by the IV method are significant at the 0.01 level. A clear trend appears that the sign of the coefficient for $\Delta CID_{k,t}$ is negative at the non-crisis period which suggests that the excess return of the DF carry trade rises with the decreasing of $\Delta CID_{k,t}$. Both signs reverting in the crisis period suggests an opposite trend in the non-crisis period. It can conclude that $\Delta CID_{k,t}$ has a positive effect on the excess return on DF carry trade.

In order to measure other risk factors' effects on the excess return of the DF carry trade strategy, this section analyzes the multivariable regression, and Table 6.7 describes the results. This paper notes that the GMM-IV method represents a robust estimate. From the total sample, the coefficients of TED are positive significant at all forward maturities. This finding suggests that if the funding market liquidity is low, then the DF excess return increases. With the growth of forward maturities, the coefficients decrease which implies that the 6 month forward shows resistance to the funding liquidity risk. Additionally, the currency crash risk proxies $SKEWNESS_{k,t}$ and $SKEWNESS_{k,t+n}$ are positive significant at all maturities which means the DF can earn an excess return from the global currency crisis. The longer the forward maturity, the larger the currency crash risk. This finding confirms that the long-maturity forward carry trade is highly vulnerable to the currency crash risk, and the FX volatility risk has a negative effect on the DF excess return. The deviation between DF and NDF carry trade return would converge if the FX market becomes volatile. Thus the forward markets have little effect on the DF excess return, but the FX spot market and funding market can influence it. The risk factors enhance the DF carry trade return although the FX volatility destabilizes this trend. When splitting the sample into a non-crisis and a crisis period, the currency crash proxy turns to be insignificant, and other risk factors remain the same in the non-crisis period. Still, seldom risk factors can explain the crisis period. The coefficient of $\Delta CID_{k,t}$ is positive significant at the 0.01 level, which is inconsistent with the previous findings. The coefficients of TED are positive significant, which confirms the result of the whole sample. In the crisis period, the coefficients of TED are negative significant at 3 month and 6 month forward carry trades. This inversion implies the illiquidity of the funding market would decrease the DF excess return, which is opposite to the non-crisis period. Besides, other alternative risk factors do not affect the deviation of DF and NDF return significantly.

In summary, the DF carry trade return dominates the NDF return due to the following reasons. First, the change of CID has a positive effect because the onshore DF price is higher than the offshore NDF price in the crisis period and lower in the non-crisis period. This premium is a capital control risk premium. Second, the funding market liquidity has an adverse effect on the DF excess return. The illiquidity in the funding market affects the NDF return more severely than the DF return, which implies that speculators who are sensitive to the funding cost prefer the offshore market. They open and close the trade action in a short period, and trade the short maturity forward. Third, the currency crash risk has a positive effect, which implies that the onshore DF market is a better place to hedge the FX risk.

Table 6.7: Alternative risk factors on deviation between DF and NDF carry trade return

1month	Total		NonCrisis		Crisis	
	DIFF	IVDIFF	DIFF	IVDIFF	DIFF	IVDIFF
$\Delta CID_{k,t}$	0.06	0.078	-0.259*	-0.244***	0.385*	0.408***
	-0.12	(0.057)	(0.084)	(0.037)	(0.112)	(0.093)
$SPREAD^{ndf}_{k,t}$	-0.13	-0.146	-0.129	-0.169	0.140	0.175
	-0.488	(0.543)	(0.436)	(0.429)	(1.385)	(1.483)
$SPREAD^{df}_{k,t}$	-0.015	-0.000	0.706	0.700	-1.120	-1.090
	-0.554	(0.541)	(0.407)	(0.433)	(1.484)	(1.419)
$FXVOL_{k,t}$	-0.38	-0.126	-1.226	-1.128*	7.698	7.246*
	-1.313	(0.628)	(0.872)	(0.488)	(5.558)	(3.229)
$TED_{k,t}$	0.011***	0.011***	0.007	0.007**	0.002	0.002
	-0.002	(0.001)	(0.003)	(0.002)	(0.002)	(0.002)
$SKEWNESS_{k,t}$	0.003	0.003*	0.002	0.003*	0.004	0.003
	-0.002	(0.001)	(0.001)	(0.001)	(0.004)	(0.005)
$SKEWNESS_{k,t+n}$	0.003	0.004**	0.003	0.003**	-0.002	-0.002
	-0.002	(0.001)	(0.001)	(0.001)	(0.004)	(0.004)
α	0.002	0.006	0.002	0.005	0.014	0.022
	-0.003	(0.004)	(0.003)	(0.003)	(0.012)	(0.013)
N	4236	4196	3693	3663	543	533
Rsq		0.262		0.311		0.464
Within R^2	0.067		0.094		0.210	
F-stat	14.382		3.705		7.004	

3month	Total		NonCrisis		Crisis	
	DIFF	IVDIFF	DIFF	IVDIFF	DIFF	IVDIFF
$\Delta CID_{k,t}$	-0.183	-0.175***	-0.452**	-0.481***	-0.012	0.079
	(0.096)	(0.052)	(0.079)	(0.043)	(0.094)	(0.118)
$SPREAD^{ndf}_{k,t}$	1.560	1.559	1.850	1.856*	0.578	-0.222
	(1.336)	(1.224)	(0.879)	(0.876)	(4.367)	(3.990)
$SPREAD^{df}_{k,t}$	2.853	2.846*	1.296	1.268	3.215	2.834
	(1.383)	(1.217)	(1.062)	(0.899)	(4.219)	(3.923)
$FXVOL_{k,t}$	-2.281	-2.226**	-2.312*	-2.368***	5.167	3.609
	(1.019)	(0.858)	(0.637)	(0.661)	(7.467)	(5.915)
$TED_{k,t}$	0.007	0.007***	0.018	0.018***	-0.010	-0.009**
	(0.004)	(0.002)	(0.009)	(0.005)	(0.004)	(0.003)
$SKEWNESS_{k,t}$	0.006	0.006**	0.003	0.003	0.014	0.013
	(0.003)	(0.002)	(0.002)	(0.002)	(0.008)	(0.008)
$SKEWNESS_{k,t+n}$	0.005	0.005*	0.003	0.003*	0.005	0.004
	(0.002)	(0.002)	(0.002)	(0.002)	(0.009)	(0.010)
α	-0.007	-0.014**	-0.004	-0.012**	0.009	0.008
	(0.005)	(0.005)	(0.005)	(0.004)	(0.020)	(0.024)
N	4213	4187	3667	3647	546	540
R-sq		0.177		0.274		0.265
Within R^2	0.053		0.170		0.019	
F-stat	6.928		12.415		2.071	

6month	Total		NonCrisis		Crisis	
	DIFF	IVDIFF	DIFF	IVDIFF	DIFF	IVDIFF
$\Delta CID_{k,t}$	-0.229	-0.197**	-0.563***	-0.608***	-0.040	0.212
	(0.100)	(0.070)	(0.083)	(0.051)	(0.157)	(0.201)
$SPREAD^{ndf}_{k,t}$	3.777	3.872*	1.068	1.006	6.144	6.584
	(1.735)	(1.697)	(0.967)	(0.894)	(3.596)	(3.465)
$SPREAD^{df}_{k,t}$	-1.309	-1.423	0.121	0.165	-4.661	-6.495
	(1.873)	(1.586)	(0.852)	(0.844)	(4.401)	(3.564)
$FXVOL_{k,t}$	-2.299*	-2.321**	-1.726*	-1.804***	-2.812	-7.680
	(0.931)	(0.762)	(0.618)	(0.481)	(7.967)	(7.856)
$TED_{k,t}$	0.005	0.004*	0.031*	0.032***	-0.011	-0.013**
	(0.003)	(0.002)	(0.010)	(0.006)	(0.006)	(0.004)
$SKEWNESS_{k,t}$	0.006	0.007**	0.003	0.003	0.011	0.009
	(0.003)	(0.003)	(0.002)	(0.002)	(0.008)	(0.010)
$SKEWNESS_{k,t+n}$	0.009	0.008**	0.003	0.003	0.025	0.024
	(0.004)	(0.003)	(0.002)	(0.002)	(0.012)	(0.013)
α	-0.010	-0.015	-0.007	-0.015**	0.001	0.019
	(0.008)	(0.008)	(0.006)	(0.006)	(0.020)	(0.035)
N	4133	4103	3587	3563	546	540
R-sq		0.163		0.298		0.256
Within R^2	0.043		0.201		0.030	
F-stat	4.263		10.988		1.676	

* Note: this table reports the estimated coefficients of Eq.(15). This paper denotes *, **, and *** for significance at 0.10, 0.05 and 0.01 levels, respectively. The standard errors, reported in parenthesis, are fixed-effects (within) (Driscoll and Kraay 1998) and GMM-IV estimators.

Chapter 7

Conclusion

The carry trade in Asian emerging markets becomes necessary after the financial crisis. With the growing amount of derivative markets, investors can hedge exchange risk and make a persistent profit. However, this return is not riskless; it depends on the convertibility risk created by the emerging market to control the capital flow. So this paper examines performances of carry trade strategies for Asian currencies with both NDF and DF contracts and sheds light on the risk of capital controls on carry trade returns, using a sample of seven countries in the period from September 2002 to June 2016. This paper finds that the performance of carry trade with 1 month forward is better than longer maturities based on the Sharpe ratio indicator. Moreover, comparing different markets, the strategy using onshore DF performs better than that using offshore NDF as a hedge choice in the whole sample period, especially the financial crisis.

Through statistical estimation, the CID has a significant positive effect on carry trade returns. The influence is even significant in DF carry trade strategies. This finding indicates that the onshore market has a stricter capital control than the offshore NDF market. Multivariate regression results prove that besides the convertibility risk, alternative risk factors such as the liquidity risk, the FX volatility risk, and the currency crash risk do not have a significant persistent effect on carry trade returns. Only the funding market liquidity can partially influence the carry trade return negatively. The difference between DF and NDF carry trade returns reports the characteristics of onshore and offshore markets. The onshore market has a capital control risk premium and invulnerable to the currency crash risk. The speculators prefer the NDF market than the DF market for a liquidity premium reason.

Part II

Second Part

Chapter 8

Introduction

The influence of the renminbi (RMB) on the foreign exchange market and international trade has been growing in recent years as the Chinese economy expanding since the financial crisis. According to the latest Bank of International Settlements Triennial Central Bank Survey on the foreign exchange market, RMB now ranks as the sixth most traded currency in the world. The internationalization of RMB may benefit the Chinese economy from reducing the exchange risk of international trade and investment, thereby reducing transaction costs. The People's Bank of China (PBoC), the central bank of China, founded an offshore financial market that can trade offshore RMB known as CNH. This action is a trial of RMB internationalization and a controllable experiment for exploring the possibility of domestic financial system further liberalization in 2009. Unlike the onshore foreign exchange market (CNY market), the offshore market (CNH market) is a relatively free capital market without capital flow restrictions. Participants in the CNH market are highly diversified. Besides, the CNH exchange rate is unrestricted by a daily trading band and free from direct intervention from PBoC. In comparison the offshore market, the onshore FX market remains highly regulated in China. Participants in the onshore FX market are limited to state-owned commercial banks, financial companies (including sub firms of large SOEs), and sub-branches of foreign banks. The central parity rate, which is subject to a 2% trading band, is set as a weighted average quote price at the beginning of each trading day by the PBoC's calculation guidance. From intuition, the offshore market is more efficient than the onshore market and free from capital flow restrictions so that the CIP should hold in the offshore market and fail in the onshore market. However, the market observations do not reflect the theory derived conclusion. The onshore covered interest deviation (CID) is smaller than the offshore CID, although they are not significant equal to zero.

In a trend of zero interest rate in developed countries, a high-interest rate in China onshore market has made RMB an attractive target for currency carry trade but imperfect one due to major obstacle–the capital control policy. Although the PBoC has allowed channels for physical investment like a foreign direct investment(FDI) and small quota-based portfolio investment via qualified foreign institutional investors (QFII), those capital flows are difficult to use for constructing carry trades. Even though the Chinese government is announcing further currency liberalization, it still wants to keep RMB at a relatively low (2% limitation) daily fluctuation and managed floating regime so that the government can intervene in markets with several tools. Both capital control restriction and government intervention impede the real price discovery and reduce market efficiency. Because of the capital control policy, onshore and offshore markets are segmented, causing a consistent price gap of RMB exchange rates, which is called the CNH-CNY difference. Because China's domestic labor market continues to shrink, the share of export in China's GDP has been decreasing after the financial crisis. The new scenario indeed terminates the fundamental structure for the current Chinese monetary system driven in the past 40 years. Export has brought China a massive foreign exchange accumulation due to an undervalued currency and export companies' mandatory USD settlement with state banks. As export declines, the massive FX reserves start to shrink. After 2014, RMB started to depreciate against USD, and both RMB exchange rates and the CNH-CNY difference experienced high volatility at the same time. This depreciation trend thrived the export again. On the offshore RMB money market, the declined liquidity caused Hongkong interbank offered rate (HIBOR) fluctuating apart from Shanghai interbank offered rate (SHIBOR), which increases the carry trade cost, because of PBoC intervened on offshore markets through state-owned banks to threaten the CNH short side to smooth the impact on China RMB. Unlike the previous regular intervention to prevent RMB as buy-side appreciation, PBoC fears of depreciation under pressures of capital outflows and fragile asset bubbles.

These observations call for a close study on both the onshore and offshore markets of China. Some relevant questions are: Which macroeconomic and market determinants cause the difference between the onshore and offshore RMB rates? Is the capital control still binding across the border? Which policy impacts the markets? Are there any carry trade and arbitrage opportunities? To solve these questions, this paper will examine the currency market structure, implement proper empirical time-series models and variables to estimate the coefficients.

This paper contributes to the literature in several ways. First of all, it constructs an extended capital control index of China on a daily basis that fits existing yearly and monthly openness indices, eg. Schindler, Chin-Ito and Chen, Qian. Through the PCA method and adding new features, my daily index is more sensitive to policy changes than other indices. Based on the mentioned index models, this paper explores how the deviation from covered interest parity of China's exchange rate regime is affected by policy changes. In terms of policy implications, this research shows that China's capital control and government intervention can be effective in CIDs under some conditions. This sheds light on policy observers and foreign investors to understand Chinese FX markets.

Secondly, the findings in this paper confirm three determinants that have a significant influence on CIP deviations. These determining factors are the capital control restrictions (proxied by my capital control index), PBoC interventions, and liquidity risks (proxied by Treasury-EuroDollar rate (TED)). For the practical purpose, with knowledge of the estimating CID change and volatility, arbitrage and carry trade investors can gauge opportunities and their future investment decisions of the CIDs for carry trade gains.

The results show that, generally, these factors have significant effects on both onshore and offshore CIDs of China in the sample. Results for the complete sample suggest that the tightening capital inflow policy would increase the CIDs. However, the capital outflow restriction would decrease the offshore CID, not the onshore CID. Capital control restrictions have no effect on the volatility of CIDs. Furthermore, coefficients on the determinants are found to be consistent across different subsamples. With regard to government intervention, the CIDs are not significantly impacted by either direct or indirect intervention. However, these interventions can reduce the CID volatilities except the situation considering the onshore counter-cyclical factor.

The paper is structured as follows: chapter two reviews relevant pieces of literature; chapter three shows the background of Chinese foreign exchange markets; chapter four explains the dataset; chapter five presents the empirical models and market structures; the last chapter reports the conclusion.

Chapter 9

Literature Review

The Chinese foreign exchange market expansion has revitalized research interest in a capital control effect on onshore-offshore carry trades and the significance of CID. Existing studies on onshore and offshore foreign exchange markets tend to focus on causality between the two, e.g., Burdekin and Tao [2013]. They use a Granger causality test on the onshore-offshore spread. By a cointegration method, Ding et al. [2014] find that the price discovery is absent between the onshore and offshore spot markets. However, the price discovery exists between onshore spot and offshore non-deliverable forward (NDF) rates. Owyong et al. [2015] implement a bidirectional linear and nonlinear causality on several sets of spot and forward prices. Their results suggest a more robust causality running from the spot onshore rate to the spot offshore rate than vice versa, which implies that foreign impulses have influenced the domestic market. Besides trading and capital restrictions, Peng et al. [2007] finds that sentiments can spillover between the onshore and offshore markets and the relative contribution of price leadership has shifted between the onshore and offshore centers over time.

A GARCH model is another quantitative method used in research on financial markets. Maziad and Kang [2012] implement a bivariate GARCH model to understand the interlinkages between onshore and offshore markets and conclude that, while developments in the onshore spot market exert an influence on the offshore spot market, offshore forward rates have a predictive impact on onshore forward rates. Funke et al. [2015] use an extended GARCH model to measure the policy effect on both the conditional level and volatility of CNH-CNY spread. Cheung and Rime [2014] use a specialized microstructure dataset to study the CNH exchange rate dynamics and links with onshore exchange rates (CNY). They conclude that the offshore CNH exchange rate has an increasing impact on the onshore rate CNY and a significant predictive power for the official RMB central parity rate. Craig et al. [2013] attribute the CNH-CNY price differential to onshore investor risk sentiment and capital account liberalization. They apply an asymmetric self-excited threshold autoregression (SETAR) model to the daily CNY-CNH price differential from September 2010 to January 2013 and find limited integration between CNY and CNH market. These pieces of literature conclude the existence of CIP deviation on both onshore and offshore RMB forward markets.

In addition to these pieces of literature on the correlation of RMB FX markets, two kinds of literature focus on the CID using the decomposition method to explain the market segmentation. The first strand is that the liquidity risk, which affects the funding of a carry trade, is the reason for CID. Ivashina et al. [2015] conclude that banks can borrow in euros then swap into dollars to make up for the dollar shortfall, but this may lead to CID because the lack of liquidity may not take the other side of the swap trade. Brauning and Ivashina [2016] further explore the role of monetary policy in affecting global banks funding sources and the use of FX hedges. Iida et al. [2016] provide theoretical evidence to show that a monetary policy divergence between the Federal Reserve and other central banks widens CIDs, and regulatory reforms such as stricter leverage ratios raise the sensitivity of CIDs. Cetorelli and Goldberg [2012] report that global banks actively manage liquidity by using internal cross-border financing in response to domestic shocks may cause the CIDs. The other strand is the banking sector issues. Sushko et al. [2017] and Du et al. [2016] focus on the banking sector and the ability of banks to take on leverage. The key message is that the value of the dollar plays the role of a barometer of risk-taking capacity in global capital markets. When the dollar strengthens, the CIDs widen. Du et al. [2016] formally establish CIP arbitrage opportunities that cannot be explained away by a credit risk or transaction costs and present evidence that bank balance sheet costs and asymmetric monetary policy shocks are the primary factors of CIDs. Borio et al. [2016] construct empirical proxies for net hedging demands of different national banking systems and show that banking demands are consistent with the cross-sectional variations in CIDs. Liao et al. [2016] document economically significant and persistent discrepancies in the pricing of credit risk between corporate bonds denominated in different currencies. This violation of the Law-of-One-Price (LOOP) in the credit risk is closely aligned with violations of covered interest rate parity in the time series and the cross-section of currencies. One recent work, Ho et al. [2018] apply a mixture of distribution hypothesis and Veronesi [1999]'s theory to the exchange rate market and examines the response of exchange rate volatility to the market information.

Interventions from a central bank also twist forward markets that cause CIDs. This operation often happens in emerging markets. Some related pieces of literature use validated datasets from central banks like Columbia, Turkey, and Swiss to estimate effects on both the level and volatility of the exchange rates. Karacadag and Guimaraes [2004] present an empirical account of Mexician recent intervention experiences. They apply a modified generalized autoregressive conditional heteroscedastic (GARCH) approach to analyze intervention effects on the exchange rate level and volatility daily. However, against this general principle, China has set capital control restrictions on conditions under the currency depreciation pressure. Related literature to explore the intervention under capital control policies is Rincon and Cordoba [2010]. They evaluate the effectiveness of these policies for depreciating the exchange rate, reducing its volatility, and moderating the exchange rate vulnerability to external shocks. The significant finding indicates that neither capital controls nor central bank interventions used separately were successful for depreciating the exchange rate but have the side effect of augmenting its volatility. Li et al. [2017] investigate Chinas daily foreign exchange intervention through the setting and adjustment of the central parity rate. They find evidence that market developments drive Chinese daily price intervention decision regarding the Chinese currency, international currency movements, and macroeconomic conditions.

Current works of literature on Chinas foreign exchange rate have not reached the capital control policy using a daily index to measure the effect on both the level and volatility of the CID. This paper aims to fill this critical void.

Chapter 10

Background

10.1 FX markets of China

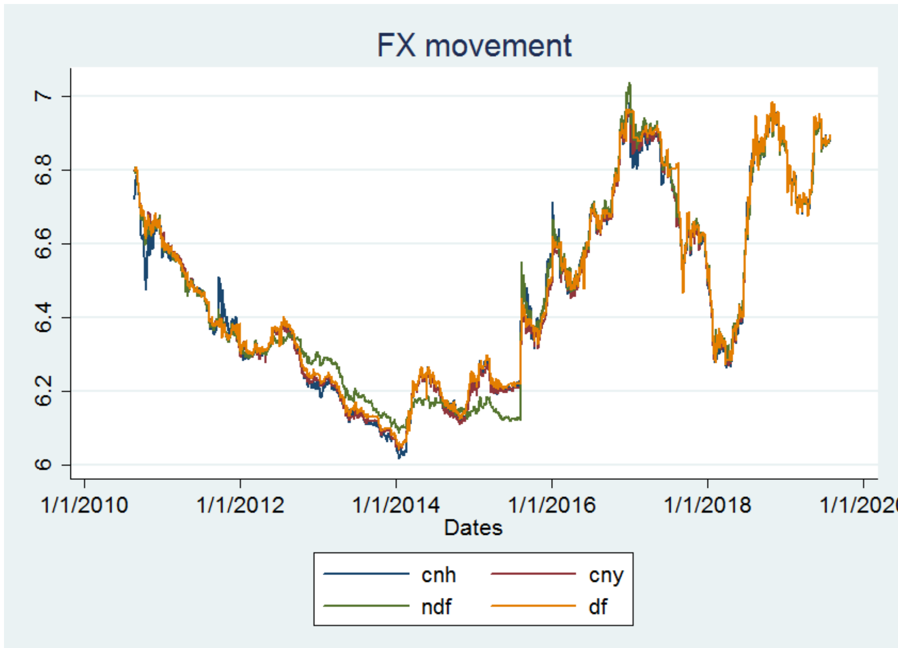
As the U.S. Treasury labeled RMB a manipulated currency, RMB became a central issue in economics research. Since 2008, the PBoC changed RMB pricing from the pegged regime to a managed floating regime. The liberalization of RMB is moving forward but slowly. Another reform, which expanded cross-border RMB trade settlement, liberalized RMB with more elasticity and started the internationalization process in 2010. The establishment of the offshore RMB FX market boosted the usage of RMB sharply.[1] IMF launched a new SDR basket, including RMB, with a weight of 10.92% in 2016. Besides, with the derivative tools allowance, investors can hedge their positions by swaps, forwards, futures and options against USD, JPY etc. One significant advantage of the RMB offshore market is that there is no restriction on CNH trading. The offshore RMB has a free-floating spot price that is accessible to

[1] The the overall proportion of China's international transactions settled in RMB reached its peak at 26% which was zero in 2010.

all investors without capital restrictions or quota requirements. Although this reform achieved some RMB liberalization, the onshore RMB CNY market remains highly controlled under the PBoC. China Foreign Exchange Trade System (CFETS), a sub-institution of PBoC, settles the central parity rate (CPR) of RMB every trading day. The settled CPR will fix the daily market trading band so that PBoC can indirectly manage the FX market by CPR against USD under a restricted 2% band after three trading band relaxations. One hedging tool for FX investors is the onshore deliverable forward (DF) traded on an over the counter basis market where both domestic and foreign investors need the authorization to participate. Though the real level of trading activity is officially unknown, daily transaction volumes are believed to be higher than $600 million. Onshore deliverable forwards have standardized maturities of 1, 3, 6, 9, and 12 months whereas longer, less liquid maturities occasionally trade (Wang [2015]).

Figure 10.1 shows two stages of these prices movement. Before 2015, these prices have a specific trend and expectation. The DF has a premium than other prices before 2014, and the NDF price premium increased after the 2015 currency reform. This evidence shows that the DF had a disparity with the NDF, indicating a higher degree of market segmentation. Because of the capital control and illiquidity cost forming the market segmentation, the positive NDF premium reflects binding capital controls or high liquidity costs. Therefore from figure 10.2, the conclusion is that capital control loosed a little bit in 2015 but turning tight again. This observation suggests that capital control restrictions had a more substantial impact on the onshore DF rate than the offshore NDF rate. These three series experienced a trough around 2013 and a peak around 2015. The first spike is due to the easing of money supply and expanding the floating band of RMB from 0.5% to 1% by the PBoC. The RMB exchange rate appreciated to 6.08 against the USD.

Figure 10.1: Onshore and Offshore RMB Movements

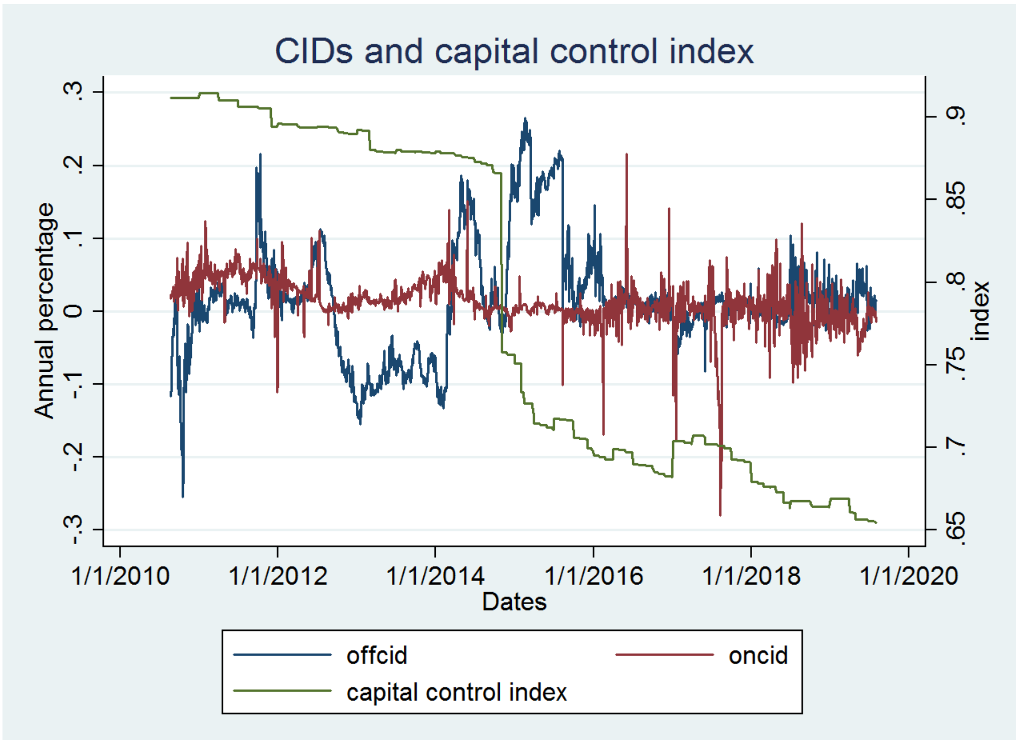


Source: Bloomberg Daily Basis

The second premium spike around 2015 can be explained by the capital outflow and FX reserve contraction. The real estate bubble accumulated huge profits for firms and households, the demand for global investments and fear of further RMB depreciation causes a massive capital outflow under relatively relaxed capital control. Then after the depreciation peak in 2017, CNH, CNY, NDF and DF movements became collaborated. Forwards cannot have a price prediction due to the high management from the PBoC so that the volatility increased in RMB FX markets. According to the tension of ChinaUnited States Trade War started in 2018, RMB depreciated quickly to compete for the rising tariff. However, as the U.S. Treasury labeled

RMB as a manipulation currency, whether the PBoC managed the depreciation is still ambiguous since the fundamental statistics of China were weak to support the currency fundamental.

Figure 10.2: Onshore and Offshore CIDs and Capital Control Index



Source: Bloomberg daily Basis

10.2 Capital Control Policies

While the current account of China opened after joining WTO in 2001, capital and financial accounts are semi-open and highly controlled by the Chinese government that is concerned with capital flights and financial crises. They simultaneously pay close attention to links between capital and current account transactions, such as fake invoicing, to avoid the restriction. One such notorious trade is the current account transaction between China mainland and Hong Kong, which is a usual channel of evading the capital control. As a result, the government controls foreign transactions under the current account, including forced foreign currency settlement of export firms and import quota on import firms. On the household side, the annual money exchange quota is fifty thousand USD per person. Households need provincial reasons to transfer this amount to foreign accounts. The governments attitude on capital control regulations changes with the macroeconomy fundamental. China accumulated the largest foreign reserve in the world and became one of the top foreign holders of US Treasuries, however, households and firms do not have access to foreign assets. Before 2008, government regulation was tight. Because of the fear of the recession in the financial crisis, the Chinese government loosed the monetary and fiscal policies, which are named four billion economic stimulus. This stimulus like QE in the US stopped the sliding of the economy, but it increased asset prices such as real estates and equities, vice versa, relatively low prices of foreign assets attracted Chinese firms and households to re-balance their asset portfolio. Meanwhile, the Chinese government intentionally loosed capital control to reduce the pressure of holding such vast US treasuries with a low return. Table 10.1 summarizes the policy changing from 2010 to 2019. These changes including modifications of quantities of QFII, QDII, and SWAPs, authorized investments for specific classes of assets and limited quota.

However, Chinese capital control is not entirely valid; some hidden channels under the current account are available to the carry trade strategy to cross the border. For example, exporters and importers can choose to settle in RMB at an advantageous rate, either onshore

Table 10.1: List of significant capital control policy imposed

Date	Market	Control	Description
08/16/2010	Bond	Loosen	The PBOC released a circular on the pilot program for foreign institutions' investment (using RMB fund) in the CIBM. Three types of foreign institutions were allowed to invest in CIBM (China Interbank Bond Market): Type 1: Foreign central banks or monetary authorities Type 2: RMB clearing banks in Hong Kong SAR and Macau SAR Type 3: Overseas participating financial institutions engaging in RMB cross-border trade settlement
02/14/2011	Derivatives	Loosen	SAFE Expands RMB-FX Cross Currency Swaps and Allows Currency Options
10/26/2011	FDI	Loosen	Foreign investors, including those from Hong Kong, Taiwan, and Macao, are now officially allowed to make direct investments in mainland China with offshore renminbi (RMB, Chinese yuan) funds.
12/16/2011	Securities	Loosen	Measures for Pilot Domestic Securities Investment Made by RMB Qualified Foreign Institutional Investors (RQFII)of Fund Management Companies and Securities Companies
4/3/2012	Securities	Loosen	SAFE Expands RQFII Quote to 50 billion RMB
4/16/2012		Loosen	The yuan's value was allowed to rise or fall by one percent from the central parity rate each trading day, from the previous limit of 0.5 percent.
3/20/2013	Bond	Loosen	The Chinese central bank has granted Qualified Foreign Institutional Investors (QFII) access to its onshore interbank bond market.
3/17/2014		Loosen	The yuan's value was allowed to rise or fall by 2 percent from the central parity rate each trading day, from the previous limit of 1 percent.
11/6/2014		Loosen	SAFE released QDII investmnet to foreign securities.
7/14/2015		Loosen	The central bank granted access for foreign central banks, sovereign wealth funds and international financial institutions to the domestic interbank bond market and further opened the onshore interbank foreign exchange market to such institutions on Sept 30.
1/3/2017		Tighten	China issued regulatory rules on outbound investments by centrally controlled state firms. Restrictions on purchasing foreign real estate by citizens.
3/2017		Tighten	China has sought to limit foreign exchange purchases by its citizens in an effort to conserve forex reserves. The new measure plugs one of the few remaining ways Chinese citizens get money out of the country by broadening the Rmb100,000 ($15,400) limit from a single account to a single individual.
11/2017		Tighten	Beijing further tightened controls over outbound investment by requiring regulatory approval for some foreign acquisitions conducted through an offshore entity.
26/4/2018		Tighten	PBoC prohibites RMB QDII to translate RMB to other currency assets.
6/8/2018		Tighten	PBoC increases foreign currency forward risk reserve from 0% to 20%.

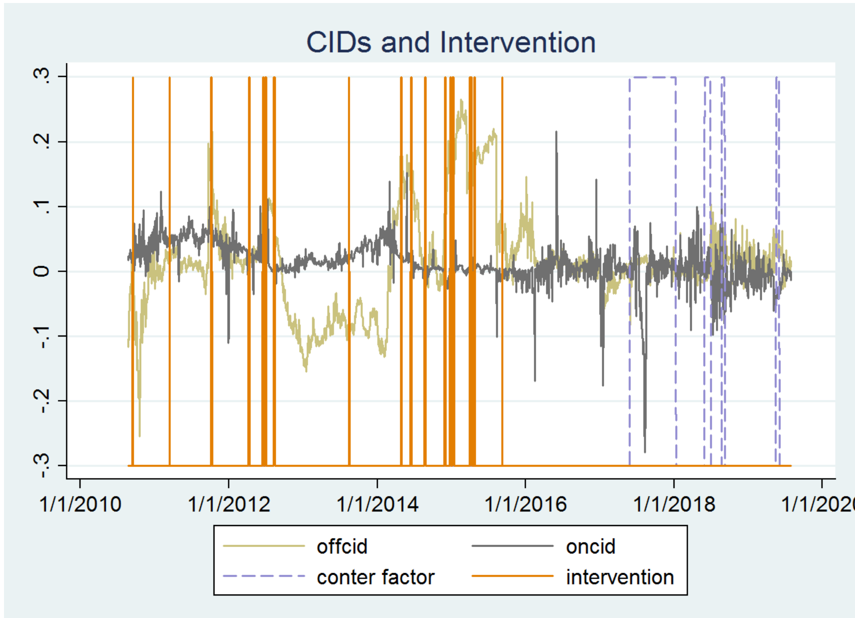
or offshore. The exporter would receive USD from its customer and sell the USD for CNY in Shanghai, as a reason that CNH usually has been more appreciated versus USD than CNY. If the invoicing is in USD, then the onshore exporter could convert that amount of USD into more RMB in the offshore market than onshore, so that the imbalance on settlement in CNH would reverse. Furthermore, there would be a net outflow of CNH deposits and a gradual reduction in the inventory of CNH. For speculators, the CNH market offers a way to skip the tight onshore capital control to make a profit from betting the inevitable appreciation of the RMB. If speculators anticipate a higher rate of appreciation, they can express that view with what is effectively a position against the PBoC. Besides the CNH-CNY difference, the interest gap between onshore and offshore RMB motivates the carry trade opportunity across the border. On average, the one month onshore SHIBOR is higher than offshore HIBOR for 2 percent. During the RMB appreciation period, carry trade investors can accumulate a positive return without the exchange risk exposure.

10.3 Foreign Exchange Intervention in China

Unlike most mature economies, China conceals its intervention quantity and time in order to achieve its target. The Chinese government intervenes in foreign exchange markets in two primary forms.

(1) The PBoC intervenes in FX markets by trading financial assets. As it involves the

Figure 10.3: Government Intervention



Source: Bloomberg Daily Basis

central bank participating in market transactions, it can be called CB intervention. Most central banks publish the quantity and date of this intervention, but China does not. However, the PBoC trade RMB assets through individual accounts like state-owned banks or concentrate the quantity in a few minutes, especially at the start or end of a trading day, to signal the expected direction to other market participants. Observing the information from markets, experienced traders can notice the intervention and make it public.

(2) The PBoC controls the level and volatile of the RMB exchange rate by specifying the central parity rate (CPR) and the range around which the daily trading prices are allowed to fluctuate. Zhang et al. [2017] call it "price intervention." With the expanding float band and an all-time accessible offshore market, this daily intervention is inefficient most of the time. The

guidance of CPR calculation is CPR:=last close price + $\alpha \times$ a basket of currency changes which is directed by the PBoC, where α is a ratio, and the basket of currency includes USD, Euro, and Yen, etc. To enhance the intervention power, the PBoC added a counter-cyclical factor into the CPR daily pricing in May 2017, which is effective in managing the price and reduce volatile of RMB. The new guidance with the counter-cyclical factor is CPR := last close price + α $\times$a basket of currency changes + counter-cyclical factor. The counter-cyclical factor is a model with features to filter out the volatile of the currency in a short period. Figure 10.3 shows the CB intervention and compares it with the price intervention.

Chapter 11

Constructing the Capital Control Dataset

According to the international finance trilemma, a country cannot have a fixed foreign exchange rate, an independent monetary policy, and a free flow of capital at the same time. As the largest mercantilism developing country, China would like to keep an independent monetary policy to support the economy growth smoothly and reduce volatile exchange rate to keep a large quantity of export. As a result, China has to restrict capital free flow by setting a brunch of control restrictions. These capital controls are sophisticated and adjusted due to domestic and global economic conditions. When the RMB internationalization becomes one target of China so far, the PBoC implements foreign exchange reforms to lose control step by step. Otherwise, the controls would be tight. This chapter focus on extracting as detailed and accurate information as possible to construct a capital control index dataset. There are two methods of openness measurements used to simulate the capital control effect de jure and de facto. The de jure method uses a qualitative judgment, in the form of a dummy, which is considered to represent whether capital controls are present. The most used de jure index is "Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER) ” which published by IMF. Although this index covers all IMF countries, it only displays annual dummy judgment on whether capital controls are valid and does not describe the changing of a countrys financial restrictions. The other method, the de facto approach, applies the degree of capital flow restrictions by including several economic features. Some recently used de facto indices are based on the Chinn-Ito index (KAOPEN) and Schindler [2009]. However, these quantitative indices still provide annual or monthly frequency data instead of daily changes. Thus, to investigate the capital control adjustment on a high-frequency basis, this paper first constructs a capital control index of China based on the Schindler [2009] structure on a daily basis. The newly constructed openness index includes four subsections from Schindler [2009] that related to the financial market. Comparing with Schindler [2009], this paper gives weight to these four subsections by their fraction relative to total financial assets. Another significant advantage of this index is that it uses the authorized quota from QFII, RQFII, QDII, and Currency SWAP as a proxy for capital openness. This delicate index can explain the CID significantly in the estimation as the signal of capital control effect.

11.1 Qualitative indices

As a daily capital control index, a qualitative index like the IMF´s AREAER and Chin-Ito with an annual frequency would not reflect the effectiveness when the restriction changes. This section follows the primary index construction method, according to Schindler [2009], with 4 AREAER asset subsections in my dataset, including portfolio equity investment, bond investment, money market investment, and derivative investment. [1] This paper codes these related financial categories in order to reflect the sensitivity of capital control policy variation.

Variable	Description
ka	Overall restrictions index
kai	Overall inflow restrictions index
kao	Overall outflow restrictions index
eq	Average equity restrictions
eqi	Equity inflow restrictions
eqo	Equity outflow restrictions
eq_plbn	Purchase locally by nonresidents (equity)
eq_siln	Sale or issue locally by nonresidents (equity)
eq_pabr	Purchase abroad by residents (equity)
eq_siar	Sale or issue abroad by residents (equity)
bo	Average bond restrictions
boi	Bond inflow restrictions
boo	Bond outflow restrictions
bo_plbn	Purchase locally by nonresidents (bonds)
bo_siln	Sale or issue locally by nonresidents (bonds)
bo_pabr	Purchase abroad by residents (bonds)
bo_siar	Sale or issue abroad by residents (bonds)
mm	Average money market restrictions
mmi	Money market inflow restrictions
mmo	Money market outflow restrictions
mm_plbn	Purchase locally by nonresidents (money market instruments)
mm_siln	Sale or issue locally by nonresidents (money market instruments)
mm_pabr	Purchase abroad by residents (money market instruments)
mm_siar	Sale or issue abroad by residents (money market instruments)
de	Average derivatives restrictions
dei	Derivatives inflow restrictions
deo	Derivatives outflow restrictions
de_plbn	Purchase locally by nonresidents (derivatives)
de_siln	Sale or issue locally by nonresidents (derivatives)
de_pabr	Purchase abroad by residents (derivatives)
de_siar	Sale or issue abroad by residents (derivatives)

The name for each index is in **black** font. In the beginning, this paper sets 4th Jan 2010 as a benchmark. The index is between 1 and 0, where 1 means totally controlled and 0

[1] Apart from Schindler [2009] this paper drops collective investment, commercial credit restrictions and financial credit restrictions, etc. because it cannot identify the weight of these asset categories from China's BOP report and collective investment, credit investment and real estate investment which are not significantly related to short term carry trades.

means free from restrictions. If there is a policy modified from tight restriction to semi-open, for example, pre-approval by regulators, the index declines to 0.5 from 1. Moreover, the index would be unchanged if there is no new policy released. This paper follows Schindler [2009]'s method to calculate an equal-weighted index by averaging the asset subsections. Table B.2 provides statistical summaries of the qualitative indices.

11.2 Hybrid indices

The qualitative indices consider the equal weight of the asset subcategories without differentiating the relative importance of each asset, which might cause some measurement errors. Like Chen and Qian [2016], this paper includes weight on each asset subsections. It settles weight according to international investment position (IIP) downloaded from the State Administration of Foreign Exchange of China (SAFE), which provides quarterly data for each asset subsections since 2011[2] disaggregated into inflows and outflows. Taking equity capital flow indices as an example, this paper lists the formulas to construct capital control hybrid indices:

$$eqi = [eq\_plbn + eq\_siar]/2 \tag{11.1}$$

$$eqo = [eq\_siln + eq\_pnbr]/2 \tag{11.2}$$

[2] The IIP shows annual data on 2009 and 2010.

$$eq = w_1 * eqi + w_2 * eqo \tag{11.3}$$

where eq, eqi, and eqo noted the index of aggregate controls on equity gross capital flows, inflows, and outflows, respectively. In qualitative indices w_1 and w_2 are 0.5. However, w_1 and w_2 are a ratio in hybrid indices, where w_1 is the equity invested by nonresident divided by the total asset of PBoC excluding foreign reserve and w_2 is the foreign equity owned by resident divided by the total liability of PBoC.

11.3 New weighted indices

Following Schindler [2009] and Binici et al. [2010], this paper constructs a new capital control dataset of China on a daily basis from Jan 2010 to June 2019 based on the public information provided from SAFE website and PBoC annual policy reports. In addition to hybrid indices in section 11.2, the available daily dataset measures the openness of financial markets by averaging the approval quota of QFII and QDII. The PBoC stopped authorization of QDII since 2016[3] however, QFII is still open to new applications. 284 international investors, including global grant banks and mutual funds, acquired quota to invest in China domestic financial market until July 2017. The quota for QDII and QFII cannot influence markets, but they show a willingness of the Chinese government towards the control of capital flow so that measuring the

[3] Chinas foreign exchange regulator in April 2018 granted combined quota of $8.34 billion to 24 institutions under QDII, according to a statement on the website of the State Administration of Foreign Exchange (SAFE). That brings outstanding QDII quotas to $98.33 billion.

indices of QDII and QFII is helpful to understand capital restrictions of China. The new index includes two subcategories “qfii ” and “qdii ” in the hybrid indices under equity, bond, money market, and derivative sub-sections. The “qfii ” and “qdii ” indices are constructed as follows:

1. The aggregate investment quota on the latest approval date as the base giving a score 0.5 which means the capital account in China needs authorization by regulators;[4]
2. The indices are constructed using quota weighted distribution between 1 to 0.5;

$$\mathrm{qfii_t} = 1 - 0.5 * \left(\frac{\text{Approved quota amount}_\mathrm{t}}{\text{Base approved amount}}\right) \tag{11.4}$$

3. The indices can be extended when the total amount of approved QFII or QDII is increasing.

The new weighted indices construction is similar to hybrid indices. Using equity as an example again, the equations used are:

$$eqi = [eq\_plbn + eq\_siar + qfii]/3 \tag{11.5}$$

$$eqo = [eq\_siln + eq\_pnbr + qdii]/3 \tag{11.6}$$

$$eq = w_1 * eqi + w_2 * eqo \tag{11.7}$$

Comparing with AREAER and other qualitative capital control index, the dataset has two significant advantages. First of all, it shows a higher frequency than annual because of this

[4]The date for qfii is may 28 2019 and Dec 4 2015.

paper accurates the policy effective date. Second, this dataset is the first daily quantitative capital control index measuring a general openness of Chinese economy and it fits existing annual qualitative and quantitative indices that use other capital control proxies. For example, Edison and Warnock [2003] who provide an extension of the liberalization analysis show that the intensity of controls at a point in time as well as their evolution over time [5] and Chen and Qian [2016] who show monthly hybrid capital control indices.

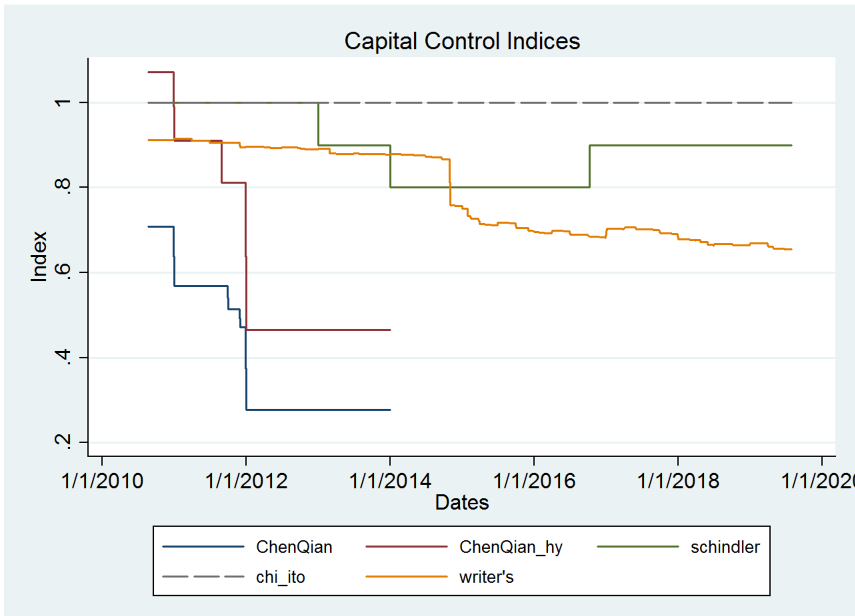
11.4 Capital control indices comparison

Like Chinn and Ito [2008], most famous capital openness indices are either an annual basis or non-sensitive to policy changing. Although they collect panel datasets covering many countries, they measure the openness of China as fully closed, which is unchanged for years. Even on a monthly basis openness index, Schindler [2009] including several subsections of capital flows, the index shows the openness of China as 1 from 2010 to 2012. Chen and Qian [2016] show two methodologies to construct unique openness indices of China. Nonetheless, a critique disadvantage of their indices is that there is no upper and lower bound of their indices. They believe that Chinese gradual liberalization of its capital account is still in process; however, this trend may reverse and if they consider each step of policy change, indices with simple adding or subtracting would not comparable with other countries using existing openness indices. Figure 11.1 shows a comparison among the index with financial capital flow measurement and other

[5] This monthly measure for emerging markets is based on the ratio of the market capitalizations underlying a country's Investable and Global indices as computed by the International Finance Corporation (IFC).

mentioned indices. The new weighted index indicates China has a tight capital control from 2010 to 2012 like Schindler [2009] and loosen the control at the end of 2011 like Chen and Qian [2016].

Figure 11.1: Capital Control Index Comparison



Source: Bloomberg Monthly Basis and Writer's Calculation

This index has several advantages comparing with existing openness indices, and it is innovative in several important ways. First, comparing with qualitative indices like Chinn and Ito [2008] and AREAER, not only give a binary capital control level on a low-frequency basis, this index measures the daily intensity of changes in Chinese capital controls. Second, although this index construction follows methodology from Schindler [2009] with an extended coding mechanism. This index reveals the milestones of Chinese policy changing on capital control and shows weightings on subsections to distinguish the actual effects of policy changes. Tables

B.2, B.3, and B.4 provide summary statistics of the indices. Third, including a binary boundary, the daily basis index is comparable with other countries by including a relative weighting capital policy measurement, this index can reflect the openness accurately.

Figure 11.2 shows the movement of the three indices. Without giving weights to each subsection, the qualitative index shows the largest decrease in a capital control policy, which indicates the largest loosen on restrictions. However, after including both weights of subsections and sensitivity of QFII and QDII capital flows, the new weighted capital index shows the tightest capital control measurement in this period. Furthermore, the weighted capital index has a high sensitivity on a daily basis. This paper will use numerical methods in the next chapter to show the factor analysis of these indices by regression models.

Figure 11.2: Author's Capital Control Indices

Source: Bloomberg, SAFE and author's calculation

Chapter 12

Determinants of onshore and offshore CIDs

12.1 Baseline model

My empirical study utilizes factors derived from Eqs.(12.1) to test whether deviations from covered interest parity (CIDs) are in response to the capital control risk, government intervention and other liquidity factors by estimating the following regression:

$$\begin{aligned} CID_{i,t} = & \alpha + \beta_1 * Index_t + \beta_2 * Int_t + \beta_3 * CPR\_dev_{i,t} + \beta_4 * CCF + \\ & \beta_5 * TED + \beta_6 * Liq_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{12.1}$$

where $CID_{i,t}$ is the deviation from CIP on time t by forward i either onshore or offshore, $Index_t$ is the capital control index proxied for the capital control risk; Int_t is the government intervention; CPR_dev is a widely used proxy of China foreign exchange intervention which is calculated by the deviation from the spot rate to the central parity rate; CCF represents Counter Cyclical Factor indirect intervention; TED represents world money market liquidity risk; $Liq_{i,t}$ is the proxy for liquidity risks. α is the intercept, βs are the estimated coefficients, and $\varepsilon_{i,t}$ is the residual.

CID reflects the risk premium across countries, such as capital controls, transaction costs, default risk, and the expectation of future uncertainty. This index calculates CIDs through both onshore and offshore financial markets.

$$CID_t^{on/off} = \left[i_t^{on/off} - i_t^* - \left(f_t^{on/off} - s_t^{on/off} \right) \right] \tag{12.2}$$

where i_t^* represents the 1 month Libor rate of the US dollar.

The spread between the bid and ask price suggests the willingness to meet the deal by investors. The trade settles only if the bid and ask price converge, which means either a buyer or seller accepts the transaction cost. Following Menkhoff et al. [2012], this paper employs the FX bid-ask spread of spot exchange and the forward market as my targeting currency cost measure. This paper calculates the bid-ask spread $LiqR_t$ as follows:

$$LiqR_t = \frac{1}{T} \sum_{t=1}^{T} BAS_t \tag{12.3}$$

where BAS_t is the percentage bid-ask spread on day t. On daily bases $T = 1$ in this paper. The larger is $LiqR_t$, the larger of liquidity cost in the markets.

The funding side uses TED spread to measure the secured funding liquidity (Brunnermeier and Pedersen [2009]). TED spread is the interest rate difference between three-month euro interbank deposits (LIBOR) and three-month Treasury bills. This spread suggests the willingness of the bank to provide funding in the global interbank market. A higher TED_t spread represents illiquidity in the global funding market for arbitragers.

The CFETS, authorized by the PBoC, calculates and publishes the central parity rate (CPR) of RMB against USD on each business day. This CPR_dev is settled by

CPR_dev = CPR − CNY or CNH [1] This deviation represents the intervention of the PBoC to set a range that prices are bound to fluctuate.

This paper considers possible channels of endogeneity that may bias the estimation and show that they are not possible to dominate my results. The one period lag of independent variable CaR_{t-1} is predetermined, which is irrelevant to the current error term ε_t from Eq.(12.1) and it has a high correlation with CaR_t. So CaR_{t-1} is chosen as the instrument variable for CID_t. This paper implements the Durbin-Wu-Hausman test and weakness IV test.

12.2 Intervention on volatilities of CIDs

The NDF and DF CID series shows evidence of volatility clustering from Figure B.2. The results indicate that the test statistic cannot reject I(0) at 1% significance. Engle (1982)

[1] All variables are in log form.

and Bollerslev (1986) showed that volatility clustering, or conditional heteroscedasticity, can be modeled using a simple generalized autoregressive conditional heteroscedasticity model–[GARCH(p,q)]. This paper extends the basic GARCH(1,1) model by adding explanatory variables in the conditional variance equation. Based on Funke et al. [2015], simple GARCH(p,q) models are unlikely to capture the actual data generation process, and more flexible modeling of the mean and conditional variance dynamics will undoubtedly improve the explanatory power of the model. The estimation model is:

$$CID_t = \mu + \sum_{i=1}^{N} \phi_i CID_{t-i} + \varepsilon_t \tag{12.4}$$

$$\varepsilon_t = \sqrt{h_t} z_t \tag{12.5}$$

$$h_t = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i h_{t-i} + \sum_{k=1}^{K} \psi_k \xi_{t-k} \tag{12.6}$$

where z_t is assumed to be an iid N(0,1) random variable, h_t is the conditional variance of ε_t given ε_t, $s < t$, $\omega > 0$, and the α_i and β_i parameters are assumed to be positive to ensure that the conditional variance h_t is positive. The lagged dependent variables typically capture autocorrelation caused by market micro structure or non-trading day effects. ψ is a k$\times$1 vector of (daily) exogenous explanatory variables that may account for the heteroscedastic nature of disturbances.

Chapter 13

Data

This section obtains the daily spot exchange rates, 1 month onshore and offshore forward rates quoted against the U.S. dollar from the Bloomberg database. For the estimation, daily (close-of-business) data from Aug 2010 (when quotes for the CNH repo rate became regular) to July 2019 are used, excluding weekends and other non-trading days such as holidays. However, the DF rates are available since Aug 2011 for China. The dataset contains both bid and ask rates on all prices. The ask (bid) rates are the rates at which a trader in the inter-dealer market can buy (sell) U.S. dollars or forwards from a currency or forward dealer. The interest rate obtains 1-month and overnight interbank repurchase rate for China onshore interest rates (i) and 1-month and overnight HIBOR for the offshore (i^*). Both SHIBOR and HIBOR are repurchase rate of RMB. The TED is 3-month Eurodollar interbank deposit rate and 3-month U.S. Treasury bill rate differential. Table 13.1 documents the description and frequency of the dataset.

Table 13.1: Data Description

Variable	Description	Frequency
Market		
NDF	1 month offshore non-deliverable forward price (bid,ask,high,low,close)	D
DF	1 month onshore deliverable forward price (bid,ask,high,low,close)	D
CNH	offshore RMB exchange rate quoted in USD	D
CNY	onshore RMB exchange rate quoted in USD	D
HIBOR	HongKong Interbank Offered Rate (1 Month)	D
SHIBOR	Shanghai Interbank Offered Rate (1 Month)	D
Fundemental		
CPR	Central Parity Rate of China	D
TED	Measure of liquidity of USD	D
Policy		
Counter Cyclical Factor	PBoC actived the counter cyclical factor in setting CPR in Aug. 2018	Dummy
Capital Account Openess	Measure the capital control tightness	Index
Intervention	PBoC intervention on FX markets based on institutional trader disclosures	Dummy

Chapter 14

Empirical Results

Data shows that CIDs calculated by onshore and offshore forwards do not move in the same direction during the sample period; however, they share a relatively constant gap due to different relevant risk factors and capital controls. This chapter analyzes the sample to reach conclusions.

14.1 Descriptive of Statistics

Panel A of Table 14.1 describes the summary statistics with the mean, standard deviation, kurtosis, skewness, and numbers for the entire sample 08/2010-07/2019. The mean CID for the NDF sample is 0.0155% on a daily basis (5.657% on an annual basis). The mean CID for the DF sample is 0.0134% (4.89% on an annual basis), which is lower than NDF CID. Moreover, the volatility of offshore CID is higher than onshore CID's. From the more significant standard deviation on offshore CID, the offshore market is more efficient in reflecting risk factors and has no daily trading band obstruction. Besides, another critical observation is that the offshore market forward price usually deviates from the CPR. This supports offshore efficiency, and daily intervention impacts the offshore market.

As mentioned above, carry trade strategies suffer substantial losses due to sudden shocks like currency crashes and extreme volatilities. The activation of the counter-cyclical factor in May 2017, is a crucial signal of the RMB foreign exchange market. The whole sample is divided into two subs by that signal. The top table of Panel B reports statistics without the factor activation. The onshore CID is positively larger with less volatility than the whole sample dataset. While in the factor activation period, the onshore CID decreases but still positive. The bottom table of Panel B reports statistics with the activation of counter-cyclical factor, CIDs of two markets are smaller than non-factor periods. These statistics show that the counter-cyclical factor causes onshore and offshore markets integration. Also, the onshore CID turns negative in this period, which means the PBoC controls capital outflow. This finding proves the policy trend of PBoC that it tightened the capital control and frequently intervened to increase the transaction cost after observing the foreign reserve shrinkage.

14.2 CID and risk factors

14.2.1 regression results on the determinants of CIDs

This section investigates the connection between CID and risk factors. Eqs.(12.1) tests the conjecture estimation.

Table 14.1: summary statistics of subsamples

Panel A: summary statistics

	Mean	Std	Skewness	Kuotosis	Max	Min	OBS
offcid	0.0155	0.076	0.6154	4.059	0.2651	-0.2543	2306
oncid	0.0134	0.0324	-1.3563	15.8989	0.2161	-0.2798	2306
ndf_liq	-0.0021	0.0051	-4.0175	19.8075	0	-0.04	2306
df_liq	-0.001	0.0017	-9.3	214.2918	0	-0.0466	2306
cnh_liq	-0.0021	0.0055	-3.9858	19.6808	0	-0.04	2306
cny_liq	-0.0009	0.0015	-4.9905	72.6815	0	-0.0299	2306
ted	0.0029	0.0011	0.8018	3.0962	0.0068	0	2306
cnh_dev	0.0009	0.0076	0.3158	3.4991	0.0302	-0.0275	2306
cny_dev	0.0008	0.0061	0.7039	3.7891	0.0197	-0.0112	2306

Panel B: summary statistics of subsamples

Non-Factor	Mean	Std	Skewness	Kuotosis	Max	Min	OBS
offcid	0.0162	0.0794	0.5655	3.7083	0.2651	-0.2543	2100
oncid	0.0158	0.0283	0.1477	8.6742	0.2161	-0.1765	2100
ndf_liq	-0.0021	0.0051	-4.0239	19.8181	0	-0.04	2100
df_liq	-0.0011	0.0018	-9.458	214.9257	0	-0.0466	2100
cnh_liq	-0.0021	0.0055	-3.9709	19.4505	0	-0.04	2100
cny_liq	-0.0009	0.0015	-5.1327	74.5816	0	-0.0299	2100
ted	0.0029	0.0012	0.7965	2.9325	0.0068	0	2100
cnh_dev	0.0009	0.0079	0.3117	3.2992	0.0302	-0.0275	2100
cny_dev	0.0008	0.0063	0.6927	3.5896	0.0197	-0.0112	2100
Factor	**Mean**	**Std**	**Skewness**	**Kuotosis**	**Max**	**Min**	**OBS**
offcid	0.0082	0.0156	-0.0601	9.8231	0.0671	-0.0829	206
oncid	-0.0104	0.0547	-2.357	10.4255	0.1201	-0.2798	206
ndf_liq	-0.0025	0.0054	-3.9624	19.6108	-0.0004	-0.036	206
df_liq	-0.0007	0.0012	-2.4854	7.2997	0	-0.0044	206
cnh_liq	-0.0019	0.005	-4.119	22.223	0	-0.035	206
cny_liq	-0.0011	0.0012	-1.9694	5.6221	-0.0001	-0.0042	206
ted	0.0028	0.0007	-0.1216	5.1734	0.0045	0	206
cnh_dev	0.0009	0.0037	-0.1409	5.02	0.0133	-0.0144	206
cny_dev	0.0008	0.0032	0.4394	5.6798	0.0138	-0.008	206

* Note: This table reports the summary statistics. The subsample is divided by the FX reform on Aug 11 2015 that PBoC loosed the control of CPR and depreciate RMB at 2%.

Figure 10.2 shows the connection of 1 month NDF to 1 month DF CIDs. A consistent gap between NDF CID and DF CID, which is the cost of crossing capital control restrictions, exists before 2016. After 2016 both CIDs have a similar movement. The level of DF CID is positive most of the time; however, the NDF CID range is not subject to the capital free flow shocks. Existing capital controls can explain the positive CID on the inflow or the risk of future capital controls on the outflow. Therefore the high premium on a DF CID consists of the empirical conclusion. The changing of CID matches the capital control index.

Two estimations are worth mentioning before moving to a discussion of the results. First, the t-statistics for independent variables are potentially overstated, as there is autocorrelation in the time-series dataset. Therefore the model uses the Newey-West robust method with an adjustment for autocorrelation in addition to possible heteroskedasticity. Second, this section conducts a Pearson correlation test and finds that all of the correlations among the variables included in our models are lower than 0.5. To further ensure that multicollinearity is not a problem, this paper calculates the variance inflation factors (VIF) for each independent variable. These VIFs never exceed 2, which suggest that our models are not prone to serious multicollinearity problems.

This paper investigates the relationship between CIDs and several key risk factors in this section and separates the dataset by currency reform using to measure the effects. This paper checks the heterogeneity and cross-section correlation of the sample. The results show that the sample is homogeneity but has AR(1) autocorrelation on residual. Newey White method is used to solve the problem.

Table 14.2 reports the results for the risk factor sensitivities in the first column for the full sample. Eq.(12.1) estimates with CIDs as the dependent variable and capital control, intervention, counter cycle factor, and liquidity risks as the independent variables. The top table shows the onshore CID, and lower shows the offshore CID. In the full sample of onshore and offshore CIDs, the estimated coefficient for the weighted capital control index is 0.175 and 0.034, respectively, statistically significant at the 0.01 significance level. The positive coefficients support the hypothesis that CIDs are positively correlated with the capital control index, which is a transaction cost measurement. For example, a 0.1 unit increase on the weighted capital control index would cause an annualized 0.175% increase on a daily onshore CID and an annualized 0.034% increase on a daily offshore CID. Therefore when the capital control tightens, the onshore CID is higher, and the offshore CID is also impacted but with less amount. An intervention is significantly related to both onshore and offshore CIDs at the total sample and across most subsamples except for the onshore depreciation part and the offshore appreciation part, which indicates the regulators would like to affect CIDs through the direct market intervention to prevent the market inefficiency. By the way, the direct intervention decreases the onshore CID by 60 basis points; however, it increases the offshore CID by 110 basis points. This intervention is one reason for the shrinkage of PBoC's foreign reserve. An alternative intervention is a deviation from the central parity rate, which can be seen as a daily intervention. The coefficients of cny_dev and cnh_dev are positive significant in most periods in the offshore CID estimation, which concludes that the intervention of PBoC is effective in the offshore market.

So that the offshore market is still under control from the Chinese government. The positive coefficients reveal the target of the intervention from the PBoC that they would like to increase the carry trade profit margin in order to prevent a short term capital outflow. The counter-cyclical factor, which is a recently announced intervention tool, is insignificant in the estimation. This finding explains that this intervention tool does not affect the level of CIDs.

Besides the capital restriction and intervention, other risk factors such as the global liquidity (TED), the forward market liquidity (ndf_liq and df_liq) and the FX market liquidity (cnh_liq and cny_liq) are included in my estimation. In both markets, the coefficients of liquidity risk factors are not significant at most of the time. In the appreciation period, the onshore forward liquidity and offshore FX liquidity are negative significant to CIDs, which suggests that targeting liquidity risks are critical at the appreciation time. The illiquidity decreases the CID causing a price inefficiency and CIP failure. On the funding side, global liquidity risk (TED) is significant most of the time except for the appreciation period. Moreover, compared to the onshore market, the global risk (TED) is negatively correlated to the offshore CID, which matches our model that the high borrowing cost would decrease the CID in the offshore market. This finding also proves that the onshore market relies on the funding cost. As the cost increases, the CID enlarges to meet the risk premium. However, the high cost in an efficient market would eliminate the carry trade volume resulting in the offshore CID decreasing. The R2 of the regression is 26 and 88.6. There are more unknown determinants on the onshore side. Overall, these regression results corroborate that capital control restrictions and government interventions are significant risk factors of CIDs. Furthermore, the carry trade performance which is a shadow of

CID is compensated by taking convertibility and liquidity risks.

In addition to the full sample analysis, this section shows estimates of two subsamples as depreciation versus appreciation respectively. Results are consistent with the full sample on most of the factors. However, the intervention is not significant in the appreciation period. However, the daily price intervention proxied by CPR deviation is effective across these subsamples. Although offshore FX prices are free float, the limited trading band can restrict the offshore volatility. The coefficients of capital control are positive significant on offshore and onshore estimations across all subsamples, which suggests capital restrictions can affect CIDs. Due to positive coefficients, the government capital control would exaggerate the failure of CIP.

Table 14.3 divides the capital control index into inflow and outflow controls and enhanced results from Table 14.2. The coefficients of capital inflow(weighted_kai) and outflow(weighted_kao) are significant in full sample periods in both markets. However, in onshore markets, these two coefficients are positive, which means when the controls tighten, the onshore CID increases. According to the risk premium theorem carry trade profit increases as risk increases. However, in the offshore market, the outflow index coefficient is negatively correlated with the offshore CID, which suggests that the tighten outflow control has an opposite impact on the offshore market. As an efficient market, capital movement is free with little transaction costs. Furthermore, the Chinese government is not anxious about capital flow shock in the offshore market. These findings conclude that the government effectively restricted capital outflow with the fear of currency depreciation and capital flight in the onshore market but not in the off-

Table 14.2: Estimates of CID and risk factors(weighted index)

onshore	full sample	appreciation	depreciation
weightednew	0.175***	0.143***	0.172***
	(0.01)	(0.02)	(0.02)
intervention	-0.006**	-0.008*	-0.002
	0.00	(0.01)	0.00
factor	-0.007	-0.015	-0.002
	(0.01)	(0.01)	(0.01)
df_liq	0.101	-7.231***	1.978*
	(0.46)	(1.09)	(1.05)
cny_liq	-0.737	-0.705	-1.787*
	(0.49)	(0.57)	(1.07)
TED	3.006***	-3.719**	4.994***
	(0.82)	(1.53)	(1.10)
cny_dev	0.409***	1.680***	0.029
	(0.11)	(0.32)	(0.14)
cons	-0.133***	-0.088***	-0.135***
	(0.01)	(0.02)	(0.02)
N	2264	1133	1131
R2	0.263	0.315	0.216
F	61.184	30.459	22.781
R2_adj	0.261	0.31	0.211
offshore	full sample	appreciation	depreciation
weightednew	0.034***	0.073***	0.025
	(0.01)	(0.02)	(0.02)
intervention	0.011**	-0.002	0.021***
	(0.01)	(0.01)	(0.01)
factor	-0.005	0.008*	-0.020*
	0.00	(0.01)	(0.01)
ndf_liq	-0.021	-4.999	-0.07
	(0.14)	(4.43)	(0.16)
cnh_liq	0.046	-3.327***	0.091
	(0.13)	(1.05)	(0.14)
TED	-3.153***	1.892	-4.694***
	(0.89)	(1.28)	(1.32)
cnh_dev	9.566***	8.801***	9.718***
	(0.19)	(0.21)	(0.30)
cons	-0.011	-0.066***	0
	(0.01)	(0.02)	(0.02)
N	2263	1132	1131
R2	0.887	0.876	0.868
F	482.339	430.728	269.448
R2_adj	0.886	0.876	0.867

* Note: The dependent variables are NDF CID and DF CID. This paper denotes *, **, and *** for significance at 0.10, 0.05 and 0.01 levels, respectively. The standard errors are in parentheses. ka represents the capital control index.

Table 14.3: Controls on outflow and inflow(weighted index)

onshore	full sample	appreciation	depreciation
weightednew_kai	0.154***	0.126	-0.097
	(0.029)	(0.077)	(0.061)
weightednew_kao	0.051***	0.031	-0.083***
	(0.016)	(0.062)	(0.022)
intervention	-0.006**	-0.008	-0.002
	(0.003)	(0.005)	(0.003)
factor	-0.005	-0.015	-0.002
	(0.007)	(0.01)	(0.007)
df_liq	0.053	-7.008***	-1.970*
	(0.482)	(1.091)	(1.048)
cny_liq	-1.431**	-0.676	-1.995
	(0.636)	(0.576)	(1.61)
TED	3.069***	-3.426**	-5.078***
	(0.82)	(1.719)	(1.057)
cny_dev	0.305**	1.524***	-0.026
	(0.126)	(0.467)	(0.147)
cons	-0.151***	-0.093***	-0.140***
	(0.012)	(0.017)	(0.032)
N	2264	1133	-1131
R2	0.267	0.315	-0.216
F	54.752	35.484	-20.642
R2_adj	0.264	0.31	-0.211
offshore	**full sample**	**appreciation**	**depreciation**
weightednew_kai	0.135***	0.429***	-0.053
	(0.028)	(0.051)	(0.041)
weightednew_kao	-0.050***	-0.263***	-0.003
	(0.017)	(0.034)	(0.019)
intervention	0.012***	0.002	-0.021***
	(0.004)	(0.004)	(0.005)
factor	-0.001	0.007	-0.018*
	(0.004)	(0.005)	(0.01)
ndf_liq	-0.23	-1.851	-0.152
	(0.142)	(2.738)	(0.174)
cnh_liq	-0.114	-1.093	-0.014
	(0.128)	(1.112)	(0.157)
TED	-2.909***	3.119**	-4.465***
	(0.864)	(1.241)	(1.268)
cnh_dev	9.386***	8.367***	-9.655***
	(0.184)	(0.211)	(0.311)
cons	-0.040***	-0.088***	-0.017
	(0.012)	(0.023)	(0.021)
N	2263	1132	-1131
R2	0.889	0.893	-0.868
F	438.106	471.126	-240.608
R2_adj	0.888	0.892	-0.867

* Note: this table reports the estimated coefficients of Eq.(12.3). This paper denotes *, **, and *** for significance at 0.10, 0.05 and 0.01 levels, respectively. The standard errors are in parentheses, reported in parenthesis.

shore market.

14.2.2 GARCH model

Table 14.4 and 14.5 show the GARCH(1,1) model with explanatory variables to explore the level and volatility on CIDs. The parameter ϕ_1 shows high persistence in onshore and offshore CIDs, implying a stable evolution of the deviation through time. The implied half-life of a volatility shock $\frac{ln(0.5)}{ln(\alpha_1+\beta_1)}$ in GARCH model is $\frac{ln(0.5)}{ln(0.56+0.30)} = 5$ days. So this model implies that the conditional volatility is very persistent.

From the conditional variance estimation using onshore data, capital restriction, direct intervention, and forward liquidity are negative significant, which means these factors reduce the volatility of the onshore CID. The PBoC intends to apply these policy tools to not only restrict capital control but stabilize market fluctuations. However, the counter-cyclical factor and TED are positive significant in the onshore market. The counter-cyclical factor is a tool to set the exchange rate, which makes the FX market opaque so that the increasing volatility can be seen as a byproduct of an inefficient pricing mechanism. The TED is a liquidity cost. An increasing cost would raise the uncertainty on the funding capital. In the offshore market, capital control restrictions and forward liquidity are consistent with the onshore market, but the TED and counter-cyclical factor reduce the volatility. Both TED and forward coefficients are negative significant at 1% level, which suggests illiquidity enlarging the fluctuation of offshore CID. In a further step, all policy variables enter into the estimation simultaneously (Table 14.4

and 14.5, Model 7). Some variables appear to be fragile. For example, the capital control index and NDF liquidity become insignificant. One possible reason is that the timing captured by these variables may coincide with the introduction of other policies.

On the model properties, the GARCH specific variables remain largely robust in these GARCH models and prove persistent in both level and volatility of onshore and offshore CIDs. The parameters ϕ, α and β remain significant. Thus, all these results related to market risk factors do not preclude the existence of GARCH effects. The greater log-likelihood values indicate that the extended models are good statistical characterizations of CIDs.

14.2.3 discussion on offshore and onshore RMB markets

Both Chinese policymakers and international investors closely monitored RMB CIDs. At the same time, the development of Chinese financial markets has created a new era of opportunity for those who desire to understand RMB movements. So far, however, little research has been undertaken to explore deviations of the onshore and offshore RMB FX markets, given the restriction and intervention. The RMB trade settlement and capital outflow to offshore markets directly enlarge the offshore RMB markets. Liquidity risks in RMB FX markets may suggest that the availability of funds and market integration are the most significant constraints to the development of offshore RMB markets.

However, consistent onshore CID affects RMB inflow to mainland China. Even

Table 14.4: DFCID GARCH

DFCID	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mean Equation							
ϕ_1	0.856***	0.860***	0.874***	0.871***	0.850***	0.857***	0.887***
	(-0.006)	(-0.005)	(-0.006)	(-0.004)	(-0.005)	(-0.005)	(-0.006)
μ	0.003***	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***
	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Variance Equation							
weightednew	-53.305***						0.152
	(-5.22)						(-0.424)
intervention		-297.593***					-1.265***
		(-1.29)					(-0.365)
concyc			1.562***				1.587***
			(-0.2)				(-0.142)
TED				824.095***			715.145***
				(-39.833)			(-27.687)
df_liq					-549.620***		-409.426***
					(-26.2)		(-23.018)
cny_dev						-12.422	-62.192***
						(-10.16)	(-6.748)
ω	27.324***	-9.728***	-10.166***	-12.468***	-10.306***	-10.143***	-12.304***
	(-3.558)	(-0.081)	(-0.099)	(-0.177)	(-0.095)	(-0.115)	(-0.389)
ARCH							
α_1	0.401***	0.731***	0.701***	0.684***	0.578***	0.706***	0.448***
	(-0.028)	(0.036)	(0.036)	(0.037)	(0.032)	(0.038)	(-0.025)
β_1	0.401***	0.156***	0.206***	0.182***	0.170***	0.235***	0.059***
	(0.010)	(0.019)	(0.020)	(0.017)	(0.020)	(0.021)	(-0.011)
N	1810	1839	1839	1839	1839	1839	1810
logL	4914.524	4960.121	4963.794	5018.052	5010.201	4949.828	5048.164
chi2	2.30E+04	2.80E+04	1.90E+04	3.80E+04	2.80E+04	2.80E+04	1.90E+04

Table 14.5: NDFCID GARCH

NDFCID	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mean Equation							
ϕ_1	0.990***	0.990***	0.990***	0.991***	0.990***	0.987***	0.988***
	(0.003)	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)	(0.003)
μ	0	0	0	0	0	0	-0.000
	(0)	(0)	(0)	(0)	(0)	(0)	(0.000)
Variance Equation							
weightednew	-2.654***						0.541
	(0.380)						(0.373)
intervention		-0.178					-0.388
		(0.421)					(0.300)
concyc			-0.918***				-0.833***
			(0.173)				(0.147)
TED				-95.580***			-48.972***
				(8.156)			(9.567)
ndf_liq					-89.099**		-29.611
					(37.200)		(29.940)
cnh_dev						55.739***	52.406***
						(5.476)	(3.544)
ω	-7.500***	-9.775***	-9.585***	-9.687***	-9.502***	-9.765***	-9.905***
	(0.282)	(0.124)	(0.093)	(0.088)	(0.150)	(0.123)	(0.350)
ARCH							
α_1	0.463***	0.491***	0.502***	0.409***	0.486***	0.470***	0.353***
	(0.037)	(0.039)	(0.038)	(0.034)	(0.039)	(0.039)	(0.031)
β_1	0.164***	0.221***	0.170***	0.124***	0.218***	0.201***	0.051
	(0.046)	(0.047)	(0.040)	(0.040)	(0.047)	(0.046)	(0.033)
N	1809	1838	1838	1838	1838	1838	1809
logL	5277.522	5355.635	5362.727	5402.592	5356.72	5374.374	5364.909
chi2	9.20E+04	8.20E+04	7.90E+04	9.90E+04	7.80E+04	1.00E+05	1.1e+05

though PBoC aims to develop the offshore market, but the fear of losing control over the exchange rate pushes it into a dilemma that explains high-frequency interventions on both onshore and offshore markets. The estimation shows that both visible daily interventions and direct supernatural interventions from the PBoC are significant risk factors for explaining the CIDs. These interventions reduce the volatilities of CIDs. Direct interventions in the offshore market sometimes increase the cost of capital flow so that offshore CID volatilities reflect higher CNH volatilities due to the relatively small offshore RMB asset. This observation is consistent with the significance of the liquidity risk factors in the variance equation of the GARCH model. Recently, the trade war between the US and China is another attractive economic issue. The PBoC managed RMB depreciation since Aug 2015, and the activation of the counter-cyclical factor is another enhancement of foreign exhange price intervention. With an increasing tariff, the PBoC loses the control of RMB depreciation so that the US treasury designated China as a currency manipulator. However, according to the market trend, the counter-cyclical factor was activated for preventing the depreciation expectation and terminated when RMB stabilized or turned to appreciation. This paper discusses the effect of these interventions both on the level and variance to carry trades. The direct intervention reduces foreign reserves so that the PBoC seldom uses this tool after 2016. The central parity rate is an efficient tool, but cannot have a direct impact on a trending expectation.

Furthermore, the opaque FX management may raise uncertainty about the manipulation, which may cause a political issue. So that the capital control policy has advantages on both effectiveness and costs less in the FX management toolbox. In the future, the PBoC may choose this tool frequently to manage capital flow shocks then stabilize the RMB exchange rate.

Chapter 15

Conclusion

This paper estimates the capital control effect on both onshore and offshore RMB CIDs and the relationship between onshore and offshore exchange and forward rates. It has two key findings. First of all, the capital control effect, intervention, and the global liquidity risk factor are the primary determinants that affect both onshore and offshore CIDs. Moreover, these factors can explaine 80% changes of offshore CID. Based on the result of estimation, the capital control policy is the primary risk factor on both sides. This paper constructs an extended daily capital control index of China to simulate the capital control changes, which is practical effects in the estimation. The conclusion is that intervention, liquidity, and strict capital control become more significant in explaining CIDs. This finding suggests the offshore market is more efficient but still controlled by the PBoC.

Secondly, this paper models implements an extended GARCH framework to model the CIDs, allowing us to analyze the impact of various factors on the volatility of CIDs. The conclusion is that capital control does not impact the volatilities of CIDs, but the counter-cyclical factor as a currency management tool reduces CIDs' volatility. According to the carry trade investors, the offshore market is an efficient market to trade before 2016. After that, as increased volatility and high impact from onshore interventions, this strategy takes additional policy risks. In order to understand the policy-making logic of the PBoC, this paper concludes that the PBoC progressly tightened the capital control of China. This finding is opposite to the general consideration of the internationalization of RMB. After the 2015 reform, with an expand trading band and one-time depreciation, capital started to flow out of China, which exaggerated the RMB depreciation and enlarged the CID level and volatility on both onshore and offshore markets. The PBoC tightened the capital control afterward to maintain FX reserves and the market confidence by indirect intervention channels that are effective in the short run. As the direct intervention costs foreign reserves, the counter-cyclical factor's activation will be more frequently. However, the costs of these interventions are so high that the PBoC may turn to use the capital control policy to manage capital flows in order to stabilize RMB.

Part III

Third Part

Chapter 16

Introduction

The influence of RMB has been growing in recent years as the Chinese economy expanding after the financial crisis. According to the latest Bank of International Settlements Triennial Central Bank Survey on the foreign exchange market, RMB now ranks as the world's sixth most traded currency. For several years Chinese authorities have argued for the desirability of an alternative to the U.S. dollar as the key reserve currency so that they are now moving in the direction of reducing their dependence on the U.S. dollar by internationalizing RMB. The internationalization of RMB may gain benefits such as decreasing exchange risks of international trade and investment, thereby reducing transaction costs, the People's Bank of China (PBoC), the central bank of China, founded offshore markets as a trial of RMB internationalization and a harbinger for domestic financial system liberalization in Hong Kong since 2010 which is known as the CNH market. Unlike the onshore foreign exchange market (CNY market), the offshore market (CNH market) is a relatively efficient market without restrictions in the onshore market.

This study is motivated to examine China's consistent onshore-offshore CIP deviations by particular shocks. Following Liao [2016], this paper implements his model to explain Chinese onshore and offshore financial markets and fill the gap of the term spread differential and CIP violation spillover effects. This static model includes three agents - a bank, investors in the money market, and traders in currency forward market. Onshore and offshore specialized investors actively allocate assets in the money market, and forward arbitrage trader makes a profit through CIP deviations in currency forward market. Further, a representative bank connects these two markets by engaging FX hedge debt allocation. When the onshore relative to offshore credit spread (term spread) is high, the bank allocates a greater share of RMB debt in the offshore market. An increase in offshore CNH, however, generates CNH exposure, which the bank hedges through currency forwards. Alternatively, when CIP deviations (transaction cost) are large, the bank chooses to minimize two costs simultaneously and then decides on the optimal share. The two violations of money and currency markets are the primary consideration of the representative bank for debt issuance.

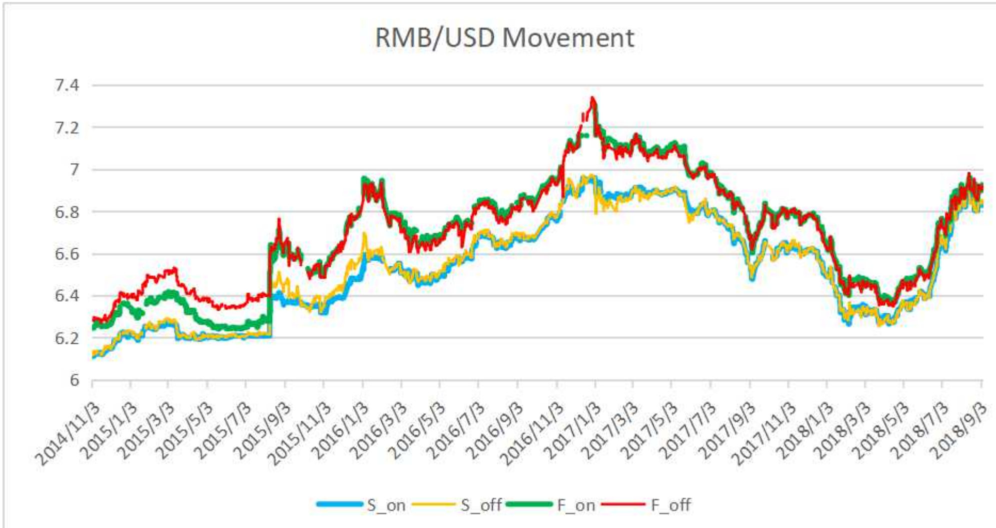
This paper estimates two types of exogenous shocks that affect this system. First, bond demand shocks in the money market are caused by monetary policy, investor preference, and money market regulatory. Second, non-issuance-related use of currency forward contracts shocks in currency forward market includes central bank policy - FX intervention, and trader expectation is driven hedging and arbitraging demands and currency market regulatory - capital control. Other pieces of literature on China's foreign exchange rate has not covered the capital control policy using a daily index to measure the level effect of the deviation from covered interest parity. This paper aims to fill that critical void. These two shocks have spillover effects from RMB spot market (money market) to forward market (currency market), and the other way around.

In money market, this paper uses offshore-onshore term spread deviations $c = (r^a_{off} - r^{o/n}_{off}) - (r^a_{on} - r^{o/n}_{on})$[1] to measure money market gaps. The Figure 16.1 shows RMB and USD exchange rate in onshore and offshore currency market. There were persistent discrepancies in the pricing of currency exchange forward between F_{on} and F_{off} before 8/10/2015. After that, but before 7/5/2017, spot exchange rates S_{on} and S_{off} existed significant gaps during some periods. Currently, the converging power shows in both onshore and offshore, and spot and forward exchange rate. In currency market, this paper calculates onshore-offshore CIP deviations $b = r^{o/n}_{on} + s - f - r^{o/n}_{off}$ to estimate currency market gaps, where the spot exchange rate between onshore CNY and offshore CNH is $1 + s \equiv \frac{S_{on}}{S_{off}}$ and the forward exchange rate is $1 + f \equiv \frac{F_{on}}{F_{off}}$. The money market offshore-onshore term spread deviations and currency market onshore-offshore CIP deviations are displayed in Figure 16.2.

Figure 16.3 reveals the consideration of representative bank that faces the total funding cost of offshore relative to onshore. Before 8/10/2015, offshore funding was better than onshore for this representative bank. Between 8/11/2015 and 7/5/2017, this representative bank would prefer to issue an onshore bond rather than borrow offshore money, due to positive gaps

[1] If $c = (r^a_{off} - r^a_{on}) - (r^{o/n}_{off} - r^{o/n}_{on})$, this equation can be interpreted to overtime offshore-onshore credit spread deviation

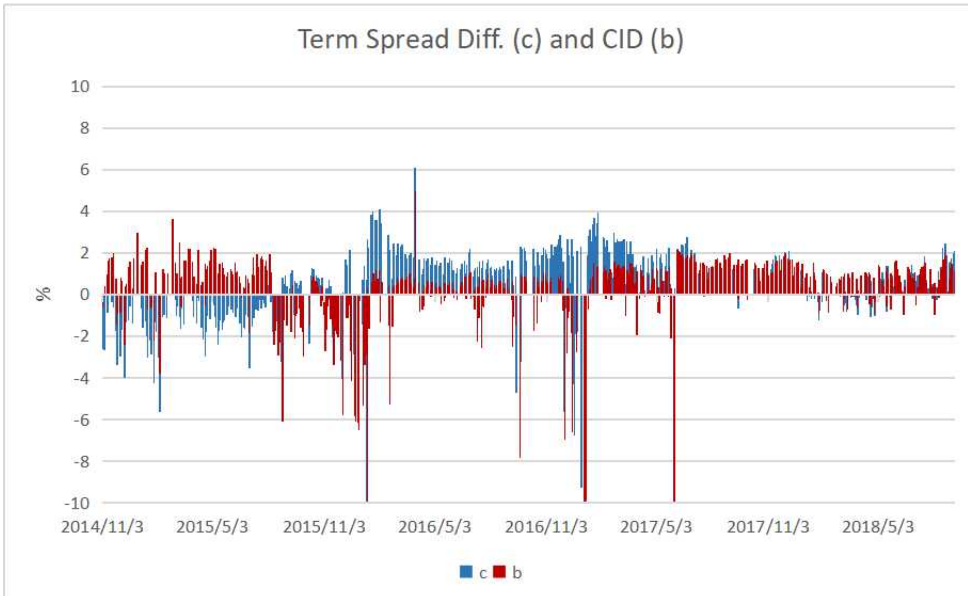
Figure 16.1: RMB foreign exchange rate movement



Note: S_{on}: onshore spot exchange rate RMB/USD; S_{off}: offshore spot exchange rate RMB/USD; F_{on}: one-year onshore deliverable forward exchange rate RMB/USD; F_{off}: one-year offshore non-deliverable forward exchange rate RMB/USD.

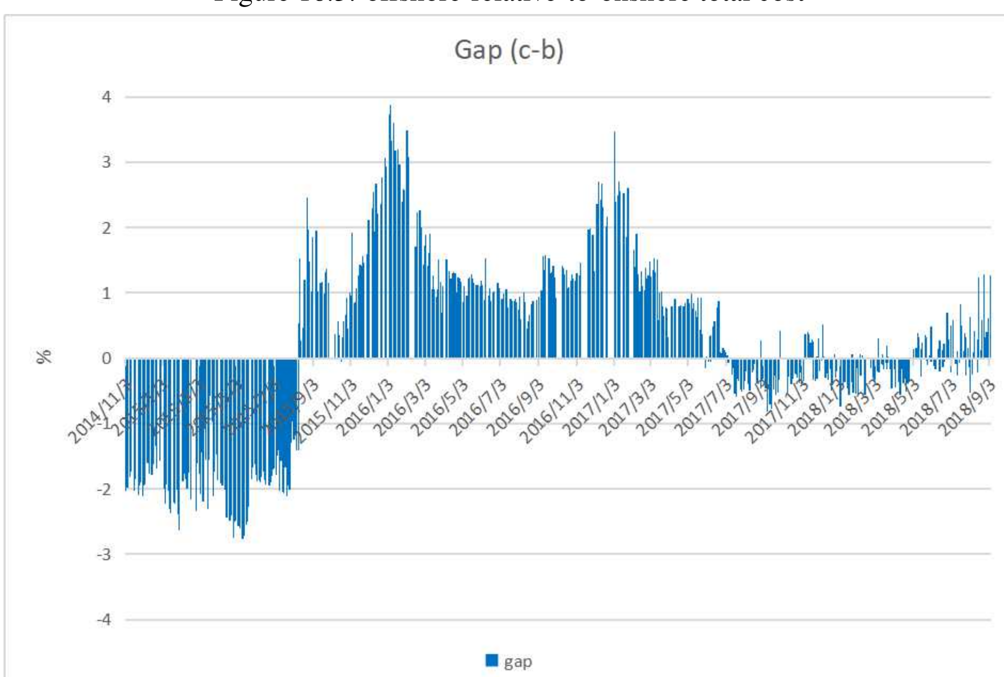
$c - b > 0$. Nowadays, the gaps are more random deviation. This paper is structured as follows: literature review in part two; modeling bank's strategy in onshore-offshore RMB money and currency markets in part three; empirical data analysis and Bayesian local projections in part four; conclusion in the last part.

Figure 16.2: Term Spread Diff and CID



Note: on 1/12/2016 c=-57.9054, b=-61.04023; on 1/5/2017 c=-52.4599, b=-54.8629; on 6/1/2017 c=-21.1185, b=-21.14572

Figure 16.3: offshore-relative-to-onshore total cost



Chapter 17

Literature review

The expanding Chinese currency forward markets have revitalized research interest in the capital control effect on onshore-offshore carry trades and the significance of CIP deviation. Existing studies on onshore and offshore foreign exchange markets tend to focus on causality between the two, e.g., Burdekin and Tao [2013]. They used Granger causality test on the onshore-offshore spread. By cointegration method Ding et al. [2014] found that price discovery is absent between the onshore and offshore spot markets; however, the price discovery exists between onshore spot and offshore nondeliverable forward (NDF) rates. Owyong et al. [2015] implemented bidirectional linear and nonlinear causality on several sets of spot and forward prices. Their results suggest more robust causality running from the spot onshore rate to the spot offshore rate than vice versa, which implies that foreign impulses have influenced the domestic market. Despite trading and capital restrictions, Peng et al. [2007] found that sentiment can spillover between the onshore and offshore markets and that over time the relative contribution of price leadership has shifted between the onshore and offshore centers.

GARCH model is another quantitative method used in the research. Maziad and Kang [2012] employed a bivariate GARCH model to understand the interlinkages between onshore and offshore markets and found that, while developments in the onshore spot market exert an influence on the offshore spot market, offshore forward rates have a predictive impact on onshore forward rates. Funke et al. [2015] implemented an extended GARCH model to measure the policy effect on both conditional level and volatility of CNH-CNY spread. Cheung and Rime [2014] use specialized microstructure dataset to study the CNH exchange rate dynamics and its links with onshore exchange rates (CNY). They conclude that the offshore CNH exchange rate has an increasing impact on the onshore rate CNY and significant predictive power for the official RMB central parity rate. Craig et al. [2013] attribute the CNH-CNY price differential to onshore investor risk sentiment and capital account liberalization. They applied an asymmetric self-excited threshold auto-regression (SETAR) model to the daily CNY-CNH price differential from September 2010 to January 2013 and found limited integration between CNY and CNH market. These literature conclude the existence of CIP deviation on both onshore and offshore RMB forward markets.

Addition to these pieces of literature on the research for the correlation of RMB FX markets, two kinds of pieces of literature focusing on the deviation of CIP through decomposition to investigate the market segmentation. The first strand is that the liquidity of the global market affects the funding of arbitrage and then causes the deviation. Ivashina et al. [2015] conclude that banks can borrow in euros and swap into dollars to make up for the dollar shortfall, but this may lead to violations of covered interest parity when there is limited capital to take the other side of the swap trade. Brauning and Ivashina [2016] further explore the role of monetary policy in affecting global banks funding sources and the use of FX hedges. Iida et al. [2016] provide theoretical evidence to show that monetary policy divergence between the Federal Reserve and other central banks widens CIP deviations and that regulatory reforms such as stricter leverage ratios raise the sensitivity of CIP deviations to monetary policy divergence by increasing the marginal cost of global banks USD funding. Cetorelli and Goldberg [2012] report that global banks actively manage liquidity using internal cross-border financing in response to domestic shocks. The other strand is the banking sector issues. Sushko et al. [2017] and Du et al. [2016] focus on the banking sector and the ability of banks to take on leverage. The key message is that the value of the dollar plays the role of barometer of risk-taking capacity in global capital markets. When the dollar strengthens, CIP deviations widen. Du et al. [2016] formally establish CIP arbitrage opportunities that cannot be explained away by credit risk or transaction costs, and present evidence that bank balance sheet costs and asymmetric monetary policy shocks are the primary drivers of CIP deviations. Borio et al. [2016] construct empirical proxies for net hedging demand of different national banking systems and show that they are consistent with the cross-sectional variations in CIP deviations. Liao [2016] document economically significant and persistent discrepancies in the pricing of credit risk between corporate bonds denominated in different currencies. This violation of the Law-of-One-Price (LOOP) in credit risk is closely aligned with violations of covered interest rate parity in the time series and the cross-section of currencies. One recent work Ho et al. [2018] applied Mixture of Distribution Hypothesis and Veronesi [1999]s theory to the exchange rate market and examined the respond of exchange rate volatility to the market information.

Chapter 18

A model of onshore-offshore money market and currency market deviations

This static model, following the idea of Liao [2016], includes three agents (bank, investors in the money market, and traders in currency forward market) and two exogenous shocks. Bank issues bonds in onshore or offshore money market and uses curreny forward to hedge offshore bond issuance. The representative bank minimizes borrowing cost to choose the share of onshore issuance. Investors in onshore or offshore money markets buy bonds. Investors would maximize investment return to choose the investment amount. Traders in currency forward market do carry trade with a forward contract. Traders would also maximize investment return to choose the investment amount. ε_c is offshore relative-to-onshore bond demand shock in the money market. Furthermore, ε_b is another non-issuance-related use of currency forward contracts shock in currency forward market.

18.1 Bank decision

A bank chooses a fixed amount of RMB debt D that needs to be borrowed and faces two costs for issuing onshore-relative-to-offshore bonds: term spread differential onshore and offshore RMB $-c = (r^a_{on} - r^{o/n}_{on}) - (r^a_{off} - r^{o/n}_{off})$, and transaction cost (CID) across the onshore and offshore boundary $b = r^{o/n}_{on} + s - f - r^{o/n}_{off}$. For term spread differential, one is the onshore CNY bond yield r^a_{on}. The other is offshore CNH bond yield r^a_{off} in offshore financial centers like Hong Kong, Singapore or London. Then, the bank observes a credit spread differential between onshore and offshore RMB bond yields to adjust risk free interest rate difference denoted as $-c = (r^a_{on} - r^a_{off}) - (r^{o/n}_{on} - r^{o/n}_{off})$, which also measures the interest rate term spread differential. If money market doesn't have arbitrage opportunity, the credit/term spread $c = 0$ fails most of time due to market segmentation. For transaction cost (CID), furthermore, if the bank borrows money from offshore market, it has an add-on cost b across the onshore and offshore boundary. This paper uses the U.S. currency as a bridge to measure this transaction cost b. If CIP holds between CNY/CNH and USD, it means $(1 + r^{o/n}_{on}) = \frac{F_{on}}{S_{on}}(1 + r_{us})$ and $(1 + r^{o/n}_{off}) = \frac{F_{off}}{S_{off}}(1 + r_{us})$, where S_{on} or S_{off} is spot exchange rate and F_{on} or F_{off} is forward exchange rate both expressed in onshore CNY or offshore CNH per USD. Then the spot exchange rate between onshore CNY and offshore CNH is $1 + s \equiv \frac{S_{on}}{S_{off}}$ and the forward exchange rate is $1 + f \equiv \frac{F_{on}}{F_{off}}$. If currency forward market onshore-offshore RMB CIP holds, the transaction cost $b = r^{o/n}_{on} + s - f - r^{o/n}_{off} = 0$ which means there would be no carry trade opportunity. Therefore, the bank chooses onshore issuance share μ to minimize onshore-relative-to-offshore bond cost.

$$\min_{\mu} (\underbrace{-c}_{\text{interest rate term spread diff}} + \underbrace{b}_{\text{transaction cost}})\mu D \tag{18.1}$$

First, if the net deviation is negative, $c - b < 0$, then the firm chooses $\mu = 0$, otherwise it chooses $\mu = 1$. Second, if the total amount of debt D is large enough, then $c - b$ is driven to zero as a result of arbitrage. According to these two derivations, two deviations c and b are aligned when a large amount of cross-market capital flows exist.

18.2 Money markets

There exist three main market participants: active offshore investors, active onshore investors, and the representative bank from above that has access to both onshore and offshore money markets. Offshore active investors focus on the investment of the offshore money market, and onshore investors invest in onshore money market exclusively. Investors borrow at the risk-free interest rate, $r_i^{o/n}$, and invest at the money market with a guaranteed yield to maturity of r_i^a, where i represents either onshore or offshore. The two bonds have an identical default probability π, loss-given-default L. The payoff of bonds has a variance of V, which is treated as an exogenous constant in the model for tractability. Onshore and offshore investors have a mean-variance preference with identical risk tolerance τ and choose investment amount X_i to solve the following

$$\max_{X_i} \left[X_i((1-\pi)r_i^a - \pi L - r_i^{o/n}) - \frac{1}{2\tau} X_i^2 V \right] \tag{18.2}$$

which has the solution $X_i = \frac{\tau}{V}((1-\pi)r_i^a - \pi L - r_i^{o/n})$ for i = onshore or offshore.

Money market clearing conditions

There is exogenous offshore-relative-to-onshore bond demand ε_c, perhaps representing demand shocks that are emerging from monetary policy, investor preference, and money market regulatory. Combining the demand with bank supply showed earlier, the market-clearing conditions for onshore and offshore money markets are

$$X_{on} = \mu D \tag{18.3}$$

$$X_{off} + \varepsilon_c = (1-\mu)D \tag{18.4}$$

Combining the investor demands with the market clearing conditions and applying first-order Taylor approximation for π around 0, money market section can derive the CNH-CNY interest rate term spread differential as:

$$\underbrace{c}_{\text{term spread differential}} = \underbrace{\frac{V}{\tau}}_{\text{elasticity}} \underbrace{\left(\underbrace{(1-2\mu)D}_{\text{relative bond supply}} - \underbrace{\varepsilon_c}_{\text{exog. bond demand}} \right)}_{\text{net bond supply offshore relative to onshore}} \tag{18.5}$$

The interest rate term spread differential c represents arbitrage opportunity in the money market since the default probability and loss given default are identical for the two bonds. Eqs.(18.5) causes that c is determined by the net bond supply between offshore and onshore money markets multiplied by the elasticity.

18.3 Currency forward market

This section describes the dynamics of the currency forward market. The insight is similar to that of money market violation, but deviation in CIP is limited by intermediary collateral and capital constraints. There are two main participants in this market: currency forward traders and issuers.

Currency forward traders choose the amount of capital to allocate to either CIP deviation, denote as b, or another investment opportunity with a profit of $f(I)$, where I is the amount of investment. The arbitrage has to set aside a haircut H when it enters the forward transaction to trade the CIP violation. Following Garleanu and Pedersen [2011], the amount of haircut is assumed to be proportional to the size s of the forward position, $H = \gamma|s|$. So, the capital allocated towards alternative investment is $I = W - \gamma|s|$. Forward traders have total wealth W and maximize the following

$$\max_{s} \quad bs + f(W - \gamma|s|) \tag{18.6}$$

which generates the direct result that the expected benefit from carrying an extra unit of CIP arbitrage is equal to marginal profitability of the alternative investment, $b = sign[s]\gamma f'(W - \gamma|s|)$. In a simple case, assume the alternative investment activity is quadratic, $f(I) = \phi_0 I - \frac{1}{2}\phi I^2$, $b = sign[s]\gamma(\phi_0 - \phi W + \gamma\phi|s|)$.

The model makes a further simplifying assumption that CIP deviation b is linearly related to the net demand for forwards, equivalently to stating $W = \frac{\phi_0}{\phi}$, which means that arbitrageur has just enough wealth W to take advantage of all positive-NPV investment opportunities in the alternative project $f(I)$. This assumption helps to reduce the constant intercept term in the equation for b, and derives that CIP deviation is proportional to forward trader position, $b = \phi\gamma^2 s$. The model normalizes $\phi = 1$.

Currency forward market clearing conditions

The representative bank from above relies on currency forward market to hedge its offshore debt issuance - amount $(1-\mu)D$ CNH. Besides, there are exogenous shocks to CIP basis ε_b that represent other non-issuance-related use of currency forward contracts. Market clearing condition of the currency forward market shows that the equilibrium level of CIP deviation satisfies

$$\underbrace{b}_{\text{CIP basis}} = -\underbrace{\gamma^2}_{\text{haircut on collateral}} \underbrace{((1-\mu)D+\varepsilon_b)}_{\text{net hedging demand}} \tag{18.7}$$

Eqs.(18.7) indicate that CIP deviation b is proportional to net hedging demand multiplied by the elasticity, which is determined by the collateral margin. Higher haircut γ strengthened the shock of hedging demand, but without net hedging demand, b does not deviate from zero.

18.4 Summary of equilibrium conditions

The three equilibrium conditions are summarized as follows (endogenous variables: c, b, μ; exogenous shocks: ε_c, ε_b.):

(1) Term spread differential (offshore-onshore):

$$\underbrace{c}_{\text{interest rate term spread differential}} = \underbrace{\frac{V}{\tau}}_{\text{elasticity}} \underbrace{((1-2\mu)D-\varepsilon_c)}_{\text{net bond supply offshore relative to onshore}} \tag{18.8}$$

(2) CIP basis:

$$\underbrace{b}_{\text{CIP basis}} = -\underbrace{\gamma^2}_{\text{haircut on collateral}}\underbrace{((1-\mu)D+\varepsilon_b)}_{\text{net hedging demand}} \tag{18.9}$$

(3) Bank choice of bond issuance ratio:

$$\mu = \begin{cases} 1, & \text{if } c-b>0 \text{ cheaper to issue in onshore} \\ 0, & \text{if } c-b<0 \text{ cheaper to issue in offshore} \end{cases} \tag{18.10}$$

With these equilibrium conditions, this model can analyze the transmission of ε_c and ε_b shocks from one market to the other.

Proposition 1. *(Spillover of deviations)* If $\varepsilon_c\downarrow$, then $c\uparrow\Rightarrow\mu\uparrow\Rightarrow b\uparrow$. If $\varepsilon_b\downarrow$, then $b\uparrow\Rightarrow\mu\downarrow\Rightarrow c\uparrow$. One market shock can transmit to the other market through capital flows. Interest rate term spread differential c and CIP deviation b reflect in the same direction to either exogenous bond demand shocks ε_c or exogenous currency forward demand shocks ε_b. RMB bond issuance μ reflect oppositely to the two shocks.

Proposition 2. *(Issuance flow and net deviation)* $(c-b)\downarrow\Rightarrow\mu\downarrow$ Cheaper net cost of issuance in offshore causes more issuance flow in offshore and less issuance in onshore.

Proposition 3. *(Arbitrage capital and aligned deviations)* Since $\frac{\partial |c-b|}{\partial D} < 0$ so that $\lim_{D \to \infty} c - b = 0$. A large amount debt issuance may decrease the absolute value of the net deviation. With infinity capital flows, the two deviations becomes identical.

Chapter 19

Empirical results

Table 19.1: Data Description

Variable	Description	Frequency
Market		
CNY (S_{on})	onshore spot exchange rate RMB/USD	D
CNH (S_{off})	offshore spot exchange rate RMB/USD	D
DF (F_{on})	1 year onshore deliverable forward exchange rate RMB/USD	D
NDF (F_{off})	1 year offshore non-deliverable forward exchange rate RMB/USD	D
SHIBOR ($r^a_{on}, r^{o/n}_{on}$)	Shanghai interbank offered rate (1 year and overnight)	D
HIBOR ($r^a_{off}, r^{o/n}_{off}$)	Hong Kong interbank offered RMB rate (1 year and overnight)	D
Bond ETFs (μ)	5-year bond ETFs traded in Shanghai and Hong Kong volume/amount	D
Shock		
RRR (ε^1_c)	required deposit reserve ratio for Mainland China	D
CSI 300 (ε^2_c)	a blue chip index for top 300 stocks in Mainland China stock exchanges	D
HSI (ε^2_c)	a blue chip index for top 50 stocks in Hong Kong stock exchanges	D
R-REPO (ε^3_c)	reverse repurchase agreements in Mainland China open market	D
BAS (ε^1_b)	bid-ask spread for exchange rate CNY/USD and CNH/USD	D
DCPR (ε^2_b)	deviations between on/offshore spot RMB/USDs and central parity rate	D
CCI (ε^3_b)	capital control index by computation	D

Source: Bloomberg, FRED, Wind and China Bureau of Statistics

19.1 Dataset

This section uses empirical data to generate endogenous variables (c, b, μ) and exogenous shocks (ε_c, ε_b) in the model. The period is from 11/3/2014 to 9/5/2018, daily data. **Interest rate term spread differential** $c = (r^a_{off} - r^{o/n}_{off}) - (r^a_{on} - r^{o/n}_{on})$ is calculated by Shanghai interbank offered rate (1 year and overnight) and Hong Kong interbank offered RMB rate (1 year and overnight). This paper assumes overnight rate is risk free rate. **Transaction cost CIP deviation** $b = r^{o/n}_{on} + \frac{S_{on}}{S_{off}} - \frac{F_{on}}{F_{off}} - r^{o/n}_{off}$ is estimated by onshore and offshore risk free rate, and CNY/CNH spot and forward exchange rates which use RMB/USD as a connection. **Capital flow onshore share** $\mu = \frac{volume_{on}}{volume_{on}+volume_{off}}$ or $\mu = \frac{amount_{on}}{amount_{on}+amount_{off}}$ is measured by 5-year bond ETFs traded in Shanghai and Hong Kong (same underlying assets) volume/amount. The two methods are highly correlated ($\rho = 0.9997$), the paper would use volume calculated μ to measure capital flow. **Exogenous bond demand shocks** ε_c in money market are caused by monetary policy, investor preference, and money market regulatory. **Exogenous currency forward demand shocks** ε_b (non-issuance-related use of currency forward contracts) in currency forward market are influenced by central bank policy - FX intervention, trader expectation driven hedging and arbitraging demands, and currency market regulatory - capital control.

19.2 Source of shocks

19.2.1 Money market shocks

Monetary policy People's Bank of China sets a reserve ratio to influence the money supply. Commercial banks are required to hold reserves against their total reservable liabilities, rather than lend out or invest. Any changes in reserve ratio would cause money market shocks, which could affect bond demand because of the different responses in onshore and offshore money markets. For instance, the central bank increases the required reserve ratio (RRR) to reduce the money supply in the economy. Therefore, the risk-free rate rises, and financial capital would flow from risky assets to safe assets. The older bonds with a relatively low premium (original yield minus new risk-free rate) would become less attractive. Demand for the bonds would decline in both onshore and offshore money markets because the low premium would not be worth taking on the risk. Due to different responses of investors, the offshore demand would reduce more than onshore, which is a negative shock on ε_c. Finally, the yield of bonds would rise until supply and demand reached a new equilibrium in each market, then interest rate term spread differential c rises. This paper uses the changed RRRs as shocks in the money market.

Investor preference The stock market is a crucial part of the financial market to investors. CSI 300 is a blue-chip index for the top 300 stocks in Mainland China stock exchanges to measure the performance of the onshore stock market. What's more, HSI is a blue-chip index for the top 50 stocks in Hong Kong stock exchanges to measure the performance of the offshore stock market. The detrended indices of daily log-form closing price are the cyclical components as shocks. The index shocks of both onshore and offshore markets are positive correlation ($\rho = 0.44$). A positive shock of offshore-relative-to-onshore stock market indices would cause capital inflow from the bond market to the stock market because of investor preference (seeking high return and low-risk assets) and substitution effect. Therefore, the offshore-relative-to-onshore bond demand shock is negative ε_c. A new equilibrium of the bond market has a higher yield of c, which is consistent with the prediction of the model.

Money market regulatory People's Bank of China could use a repurchase agreement (REPO) or a reverse repurchase agreement (Reverse REPO), classified as a money market instrument, to decrease or increase short-term liquidity as one of the open market operations. A positive shock of the reverse repurchase agreement (R-REPO) means the central bank increases short-term liquidity. In other words, the central bank purchases bonds now and agrees to sell them in the future. Then, the central bank pushes the traditional government bond investors in search of a high-yielding bond. Therefore, onshore bond demand rises (offshore-relative-to-onshore bond demand drops), which has a negative impact on ε_c. The increasing short-term liquidity would trigger that onshore yield falls, so interest rate term spread differential c rises.

19.2.2 Currency market shocks

Central bank policy People's Bank of China can implement foreign exchange intervention through changing currency liquidity. The bid-ask spread is a reflection of the demand and supply for the asset. Due to the difference in liquidity of each asset, the size of the bid-ask spread from one asset to another varies. Here, this paper uses onshore and offshore RMB/USD exchange rate bid-ask spreads to measure the onshore-offshore CNY/CNH liquidity.[1] The liquid asset has a small bid-ask spread in the currency market. A positive shock on CNY/CNH liquidity means that the spot exchange rate CNY/CNH currency market has less liquidity. From a currency market trader's perspective, liquidity is usually experienced in terms of the volatility of price movements. A liquid asset will tend to see prices move very gradually and in small increments. An illiquid asset will tend to see prices move abruptly and in large price increments. When traders face a risky currency market, non-issuance-related use of currency forward contracts ε_b increases. Thus, the offshore strategy becomes costly, then the onshore-relative-to-offshore transaction cost (CIP basis) b would fall.

Trader expectation In China's onshore spot foreign exchange market, RMB is allowed to rise or fall by 2 percent from the central parity rate each trading day, but the daily trading band does not impose on the offshore foreign exchange market. Therefore, the risk could be from a large uncertain movement of CNH/USD in the offshore currency market. The gap of CNH/USD and central parity rate is divided by the gap of CNY/USD and central parity rate to measure offshore-relative-to-onshore exchange rate volatility. If the result is less than the threshold -2, the offshore exchange rate is more volatile than onshore one with the opposite direction.[2] When traders see the more volatile offshore market and opposite deviation from the

[1]Because the spot exchange rate between onshore CNY and offshore CNH is $1+s \equiv \frac{S_{on}}{S_{off}}$, the CNY/CNH bid price is $1+s^b \equiv \frac{S^b_{on}}{S^b_{off}}$ and the CNY/CNH ask price is $1+s^a \equiv \frac{S^a_{on}}{S^a_{off}}$. Therefore, the onshore-offshore CNY/CNH liquidity gap is $s^a - s^b$.

[2]If $\frac{DCPR_{off}}{DCPR_{on}} < -2$, $\varepsilon_b = 1 + \frac{DCPR_{on}}{DCPR_{off}}$; otherwise, $\varepsilon_b = 0$. Therefore, ε_b is between 0 (less risky) and 1 (riskier).

central parity rate against the onshore market, they will use currency forward contracts ε_b to hedge risk or pursue arbitrage opportunity. As a result, the excess demands of currency forward contracts increase the cost of the offshore strategy, and CIP basis b would fall.

Currency market regulatory Capital control represents any methods taken by the People's Bank of China to limit the capital inflow and outflow to and from the domestic economy. Capital controls can affect many assets, such as bonds, stocks, and foreign exchange trades. Because the de jure indices like IMF's AREAER and Chinn-Ito with annual frequency would not reflect effectiveness after a policy changing, this paper calculates a daily capital control index which follows the basic index construction method according to Schindler [2009] with 7 AREAER asset subcategories including portfolio equity investment, bond investment, money market investment, collective investment, derivative investment, commercial credits, and real estate investment. The capital control index is between 1 and 0 to measure the degree from full capital controls to free capital flows. A positive shock of changed daily capital control index would cause more controls on free capital movement. The capital control could lower risks associated with the volatility of capital flows in the onshore currency market, but this regulatory would expand the gap between offshore and onshore currency market. Consequently, the demands of currency forward contract ε_b increase, and onshore-relative-to-offshore CIP basis b decreases.

Table 19.2: Correlation

Correlation	ΔRRR $\uparrow$	HSI-CSI $\uparrow$	R-REPO $\uparrow$
ε_c	$\downarrow$	$\downarrow$	$\downarrow$
c $\uparrow$	0.0287	0.1276	0.0448
	BAS $\uparrow$	DCPR $\uparrow$	ΔCCI $\uparrow$
ε_b	$\uparrow$	$\uparrow$	$\uparrow$
b $\downarrow$	-0.0678	-0.0473	-0.0320

19.3 Proposition 1 test

19.3.1 Bayesian Local Projection Method

Miranda-Agrippino and Ricco [2017] provided a flexible econometric method - Bayesian local projections robust to misspecifications that bridges between vector autoregressions (VARs) and local projections (LPs). The VARs produce IRFs by iterating up to the relevant horizon the coefficients of a one-step-ahead model. However, because of a small-size information set, underestimated lag order, and non-linearities, misspecified VARs can fail to capture all of the dynamic interactions. $y_{t+1} = C + B_1 y_t + .. + B_p y_{t-p+1} + \varepsilon_{t+1}$ The LPs, Jord'a[2005], estimate the IRFs from the coefficients of direct projections of variables onto their lags at the relevant horizon. However, due to the moving average structure of the residuals and the risk of over parametrization, LPs are likely to be less efficient. Hence it subjects to volatile and imprecise estimates. $y_{t+h} = C + B_1 y_t + .. + B_p y_{t-p+1} + \varepsilon_{t+h}$ Therefore, choosing between iterated and direct methods involves a sharp trade-off between bias and estimation variance: the VAR produces more efficient parameters estimates than the LP, but it is prone to bias if the one-step-ahead model is misspecified.

Miranda-Agrippino and Ricco [2017] proposed a regularization for LP-based IRFs, which builds on the prior that a VAR can provide, in first approximation, a decent description of the behavior of most variables. As the horizon grows, however, BLPs are allowed to optimally deviate from the restrictive shape of VAR-based IRFs, whenever the data poorly support these. This, while the discipline imposed by the prior, allows retaining reasonable estimation uncertainty at all horizons. Hence, BLP can sensibly reduce the impact of compounded biases over the horizons, effectively dealing with model misspecifications.

19.3.2 Impulse response functions

The main results of this section are that impulse response functions (IRFs) with two exogenous shocks differ along some critical dimensions. Figure 4 to Figure 6 shows exogenous offshore-relative-to-onshore bond demand shocks from different sources in the money market with the Bayesian local projection method. Figure 7 to Figure 9 display exogenous non-issuance-related use of currency forward contracts shocks from different sources in the currency market with Bayesian local projection method.[3]

For money market shocks, Proposition 1 test, if $\varepsilon_c \downarrow$, then $c \uparrow \Rightarrow \mu \uparrow \Rightarrow b \uparrow$. In Figure 19.1, the changed reserve ratio would cause that simultaneous effect of a 1% increase in interest rate term spread differential (offshore-relative-to-onshore money market cost) will lead a 0.3% increase in the share of onshore bond issuance which would raise transaction cost by

[3] All IRFs have a 90% confidence interval. Please see the IRFs appendix for more details with other methods - VARs and LPs

0.85% (onshore-relative-to-offshore currency market cost). In Figure 19.2, the stock market substitution effect influences the term spread differential by a 1% rise; then, offshore money market cost raises 1.1% of onshore transaction cost following by onshore issuance share 0.16% jump. In Figure 16.3, the result of reverse repurchase agreement operations is consistent with model prediction. 1% increase in c triggers around 1% increase in b through the more onshore issuance μ by 0.5%.

For currency market shocks, Proposition 1 test, if $\varepsilon_b \downarrow$, then $b \uparrow \Rightarrow \mu \downarrow \Rightarrow c \uparrow$. In Figure 19.4, CNY/CNH liquidity would cause that simultaneous effect of a 1% increase in transaction cost (onshore-relative-to-offshore currency market cost) will be a 2.5% decrease in the share of onshore bond issuance which would raise interest rate term spread differential by 1% (offshore-relative-to-onshore money market cost). In Figure 19.5, offshore-relative-to-onshore exchange rate volatility affects transaction costs by a 1% increase; then, onshore currency market cost raises 2% of offshore money market cost following by onshore issuance share 1.4% fall. In Figure 19.6, the result of capital control is consistent with model prediction. 1% increase in b triggers around 3% increase in c through the less onshore issuance μ by 3.5%.

In shorts, one market shock can transmit to the other market through capital flows. The spot money market is more sensitive to shocks from forward currency market through capital flows. The more significant capital flows under uncertainty shocks from forward currency market would cause that transaction cost is more volatile due to exchange-rate overshooting. The effects decay in a week after initial shocks, but the effect on capital flows is less persistent.

19.4 Proposition 2 & 3 tests

19.4.1 Long run propensity

The cumulative effect of a permanent change in X_t on Y_t will be the sum of the coefficients, known as the long run propensity (LRP). This paper uses Koyck (geometric lag) model to provide evidence of Proposition 2 and 3. This model allows for feasible estimation of $Y_t = \beta_0 + \delta_0 X_t + \delta_1 X_{t-1} + \delta_2 X_{t-2} + ... + \delta_q X_{t-q} + ... + u_t$ under assumption that $\delta_i = \delta_0 \lambda^i$ where $0 < \lambda < 1$. Thus, the value of the impact multipliers (δ) decreases geometrically as the associated lag (i) increases. A larger value of λ (closer to 1) means a greater persistence of lagged values. The estimation equation is $Y_t = \beta^* + \lambda Y_{t-1} + \delta_0 X_t + u_t^*$, so the long run propensity is $LRP = \frac{\delta_0}{1-\lambda}$. [4] Therefore, this model shows not only simultaneous effect, but also cumulative effect (LRP).

19.4.2 Regression

Koyck (geometric lag) model tests Proposition 2 & 3 to estimate long-run propensity, also involving endogeneity, heteroskedasticity, and auto-correlated errors problems. Therefore, this paper uses two-stage least squares (2SLS) instrumental variables and a robust standard error method to solve these problems, also adds some control variables from money and currency

[4] see Koyck model derivation appendix for more details

markets into the estimation equation. For Proposition 2, the share μ and gap $c-b$ have an endogenous problem, so the sixth lag of gap $c-b$ is the instrumental variable for the current gap $c-b$. From Proposition 1 results, the sixth lag is deep enough for an instrumental variable. The Proposition 2 test $(c-b)\downarrow \Rightarrow \mu \downarrow$ estimates insignificant $\lambda = 0.019$ which implies little persistence, and significant $\delta_0 = 0.305$ as model prediction. As a result, the simultaneous effect of a 1% decrease in offshore-relative-to-onshore bond issuance cost $c-b$ will be a 0.305% decrease in the share of onshore bond issuance. Therefore, the cheaper net cost of issuance in offshore causes more issuance flow in offshore and less issuance in onshore.

For Proposition 3, the sum of onshore and offshore bond ETFs amount is the total debt issuance with logarithmic form. Also, there is an endogenous problem. This regression chooses the third lag of *debt* as its instrumental variable. The Proposition 3 test $\frac{\partial |c-b|}{\partial D} < 0$ provides significant $\lambda = 0.854$ which implies high level of persistence, and significant $\delta_0 = -0.03$ as model prediction. The simultaneous effect of a 1% increase in total bond issuance will be a 0.03 basis point decrease in the absolute gap of interest rate $|c-b|$. However, the cumulative effect (LRP) of a 1% increase in total bond issuance will be a 0.205 basis point decrease in the absolute gap of interest rate $|c-b|$. In a word, a large amount of debt issuance may decrease the absolute value of the net deviation. With infinity capital flows, the two deviations become identical.

Table 19.3: Regression - 2SLS IV and Robust Method

	μ_share		|c-b|
(c-b)	0.305*	*debt*_amount	-0.030*
	(0.1696)		(0.0183)
L1.μ_share	0.019	L1.|c-b|	0.854***
	(0.0293)		(0.0325)
control variables		control variables	
cons	97.634***	cons	0.690**
	(2.9035)		(0.3463)
N	410	N	274
Root MSE	3.031	Root MSE	0.273

Figure 19.1: Monetary policy - changed reserve ratio $\varepsilon_c \downarrow$

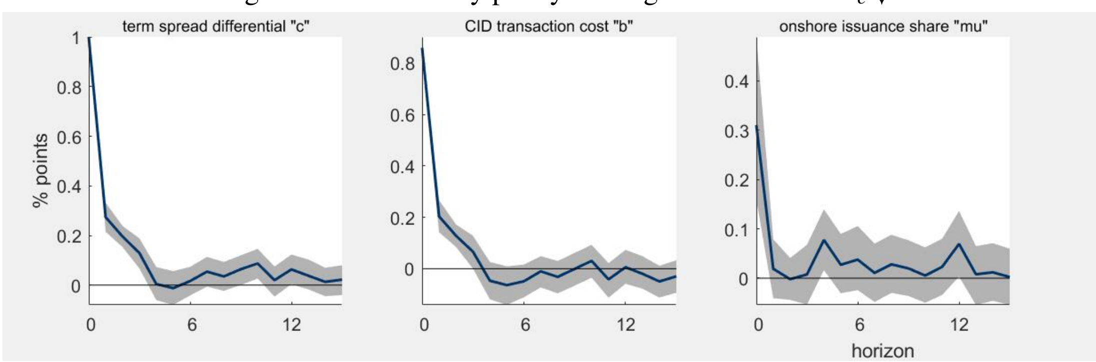


Figure 19.2: Investor preference - stock market substitution effect $\varepsilon_c \downarrow$

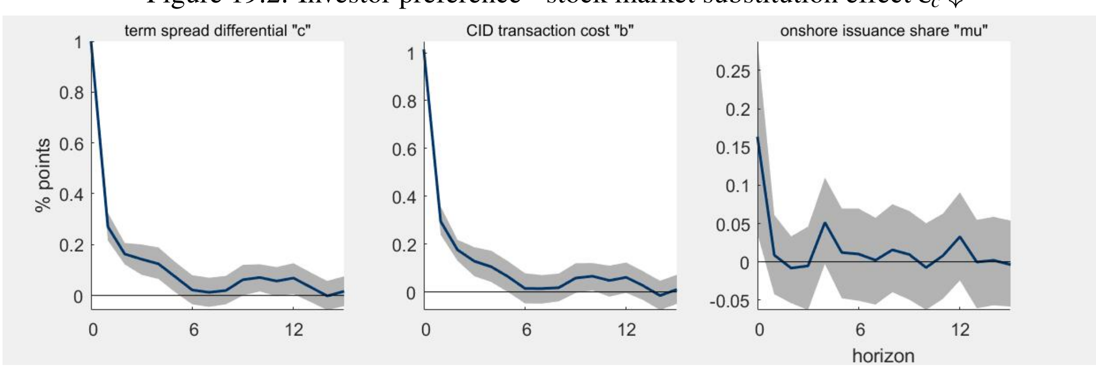


Figure 19.3: Money market regulatory - reverse REPO of open market $\varepsilon_c \downarrow$

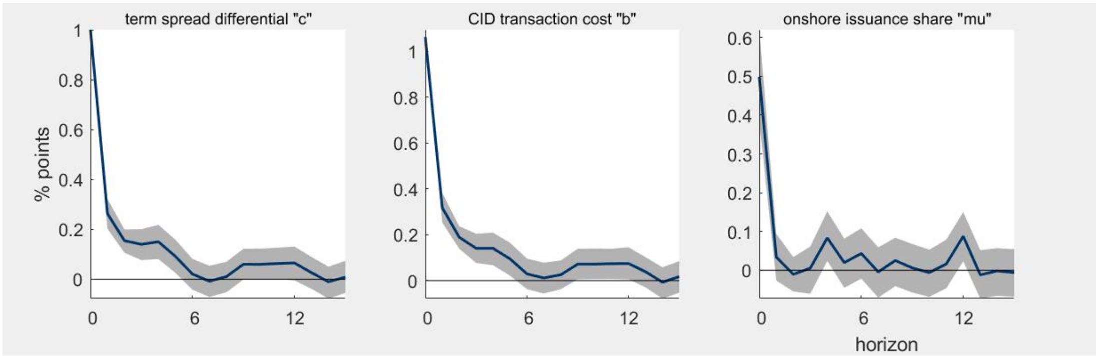


Figure 19.4: Central bank policy - liquidity of currency market $\varepsilon_b \downarrow$

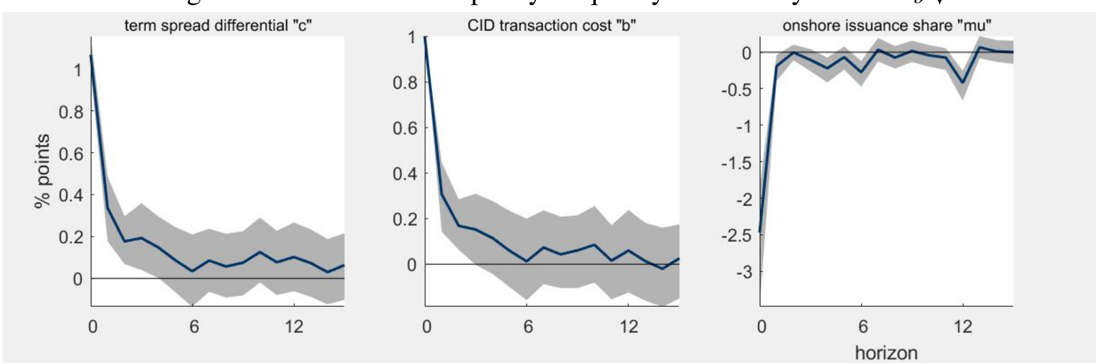


Figure 19.5: Trader expectation - volatility of currency market $\varepsilon_b \downarrow$

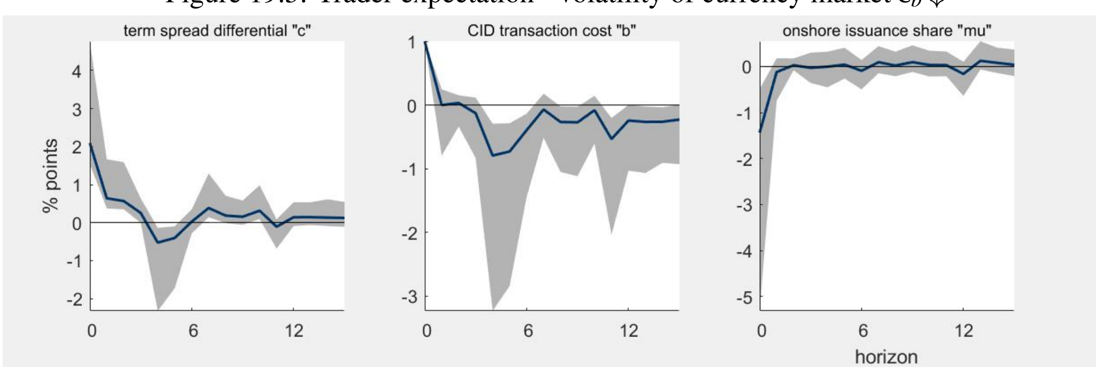
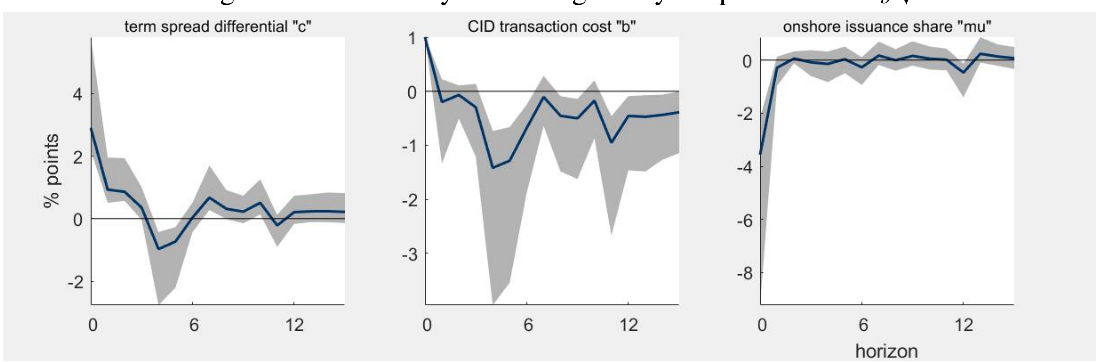


Figure 19.6: Currency market regulatory - capital control $\varepsilon_b \downarrow$



Chapter 20

Conclusion

China has both RMB onshore and offshore markets. The onshore CNY market is relatively regulated and controlled, but the offshore CNH market is relatively marketized and liberalized. The offshore market is the experimental field of RMB internationalization. This asymmetric phenomenon would cause many questions that are worth probing into. This paper implements the idea of Liao [2016] to explain Chinese onshore and offshore financial markets and fill the gap of the term spread differential and CIP violation spillover effects. From the model's results, there are three propositions under the financial institution - a bank's strategy in RMB money and currency markets. This paper also uses a flexible econometric method of Miranda-Agrippino and Ricco [2017], which can sensibly reduce the impact of compounded biases over the horizons and effectively deal with model misspecifications, to test Proposition 1 with a different source of shocks. Another econometric method is two-stage least squares (2SLS) instrumental variables and robust standard errors under Koyck (geometric lag) model to test Proposition 2 & 3 simultaneous effect and long-run propensity.

The results are three-fold: First, Proposition 1 - spillover of deviations: one market shock can transmit to the other market through capital flows. The shocks from the currency forward market have a significant impact on the spot money market through capital flows. Also, these shocks from forward currency market would cause overreacted capital flows, which makes transaction costs more volatile because of exchange-rate overshooting. The effects on both markets would die away in a week after initial shocks, but the effect on capital flows is less persistent. Second, Proposition 2 - issuance flow and net deviation: cheaper net cost of issuance in offshore causes more issuance flow in offshore and less issuance in onshore. The profit maximization behavior of financial institutions could cause bond issuance movement to lower costs. Third, Proposition 3 - arbitrage capital and aligned deviations: a massive amount of debt issuance may decrease the absolute value of the net deviation. With infinity capital flows, the two deviations become identical. The asymmetric phenomenon implies that RMB markets are less efficient, so there would be some arbitrage opportunities. However, strict regulations and high costs can turn a possible arbitrage situation into unfavorable one that has no benefit to investors and traders.

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Appendix A

Part 1 Appendices

Modified Wald test for groupwise heteroskedasticity in fixed effect regression model

H0: $sigma(i)^2 = sigma^2$ for all i

chi2 (7) = 593.68

Prob>chi2 = 0.0000

Table A.1: Correlation matrix of residuals:

	e1	e2	e3	e4	e5	e6	e7
e1	1						
e2	0.0285	1					
e3	-0.0352	-0.1601	1				
e4	0.1241	0.006	0.117	1			
e5	0.0263	0.2105	-0.2472	0.0826	1		
e6	0.1614	-0.2185	0.0843	0.1247	0.075	1	
e7	-0.1993	-0.0147	0.0121	-0.0751	-0.0185	0.0039	1

Breusch-Pagan LM test of independence: chi2(21) = 131.922, Pr = 0.0000

Based on 391 complete observations over panel units

Table A.2: Hausman Test for FE and RE

	(b) mfe	(B) mre	(b-B) Difference	sqrt(diag(Vb-VB)) S.E.
cid	-0.39933	-0.40396	0.004624	0.0007708

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(1) = (b-B)'[(V_b-V_B)$\hat{}$(-1)](b-B) = 35.98

Prob>chi2 = 0.0000

LR test for Pooled OLS and FE

Likelihood-ratio test LR chi2(6) = 93.23

(Assumption: mols nested in mfe) Prob > chi2 = 0.0000

Test of endogeneity Eq.(14)(orthogonality conditions)

Ho: variables are exogenous

GMM C statistic chi2(1) = 3.04281 (p = 0.0811)

Table A.3: Test of Endogeneity

First-stage regression summary statistics

Variable	R-sq	Adejusted R-sq	Partial R-sq	RobustF(1,4251)	Prob>F
cid	0.8829	0.8826	0.7693	4051.51	0.0000

Appendix B

Part 2 Appendices

B.1 Model Set Up

Following Sushko et al. [2017], this paper assumes risk averse UIP arbitrageurs have an exponential utility function $-E_t[exp(-\rho W_{t+1})]$. They have wealth W_t at time t and decide to invest the dollar amount $x_{t,f}$ on FX forwards, so as to maximize the utility from next period. r_t^* and r_t represent interest rates in RMB and US dollar at time t. Mancini-Griffoli and Ranaldo [2011] introduce a constant k as the fraction of arbitrage funded by repo markets with a liquidity constraint. The expected end-period wealth of the UIP arbitrageurs can be expressed as follows:

$$E_t[W_{t+1}] = W_t + (W_t - x_{t,f}(1-k))r_t + x_{t,f}(E_t[s_{t+1}^B] + r_t^* - s_t^A) - kx_{t,f}r_t^{REPO} \tag{B.1}$$

This paper assumes $E_t[s_{t+1}^B] - s_t^A > r_t - r_t^*$ and the reversion just changes results to the opposite direction. UIP arbitragers' wealth would be driven only by the relative return of $E_t[s^B_{t+1}] - s^A_t + r^*_t - (1-k)r_t + kr^{REPO}_t$. $E_t[s^B_{t+1}] \sim N(f^B_t, \sigma^2_s)$. We can derive the objective function as:

$$W_t + (W_t - x_{t,f}(1-k))r_t + x_{t,f}(f^B_t + r^*_t - s^A_t) - \frac{\rho}{2}x^2_{t,f}\sigma^2_s - kx_{t,f}r^{REPO}_t \tag{B.2}$$

As discussed in Zigrand et al. [2010], ρ represents the coefficient of absolute risk aversion.

Solving for the optimal $x_{t,f}$:

$$f^B_t = s^A_t + r_t - r^*_t + \rho\sigma^2_s x_{t,f} + k(r^{REPO}_t - r_t) \tag{B.3}$$

The last four terms in Eq.(B.3) refers that

The equation can be derived as:

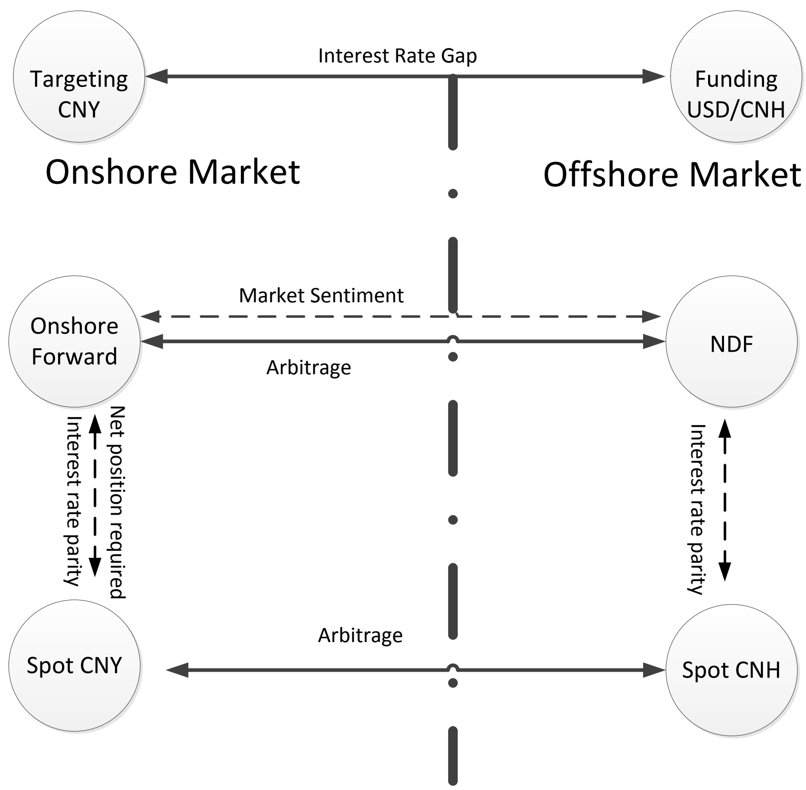
$$f^B_t = s^A_t + r_t - r^*_t - \theta C_t - \lambda I_t + \rho\sigma^2_s x_{t,f} + k(r^{REPO}_t - r_t) \tag{B.4}$$

This paper uses: capital control effect C_t, intervention shocks I_t , demand shock $\rho\sigma^2_s x_{t,f}$, leverage cost $k(r^{REPO}_t - r_t)$ and $f_t - s_t \equiv 1/2 \times [(f^B_t - s^A_t) + (f^A_t - s^B_t)]$ which represent the FX market liquidity to explain risk factors inside $\frac{\rho}{2}x^2_{t,f}\sigma^2_s$. These risks will deviate the forward exchange rates away from UIP based value which leads the deviation from CIP.

$$
\begin{aligned}
CID_t &\equiv r_t - r_t^* - f_t + s_t \\
&= \underbrace{C_t}_{\text{Capital Control Risk}} + \underbrace{I_t}_{\text{Intervention impact}} - \underbrace{\sigma_s^2}_{\text{other risks}} \\
&\quad - \underbrace{k(r_t^{REPO} - r_t)}_{\text{Secured funding liquidity}} + \underbrace{[(f_t^B - f_t^A) + (s_t^B - s_t^A)]/2}_{\text{Market liquidity}}
\end{aligned} \tag{B.5}
$$

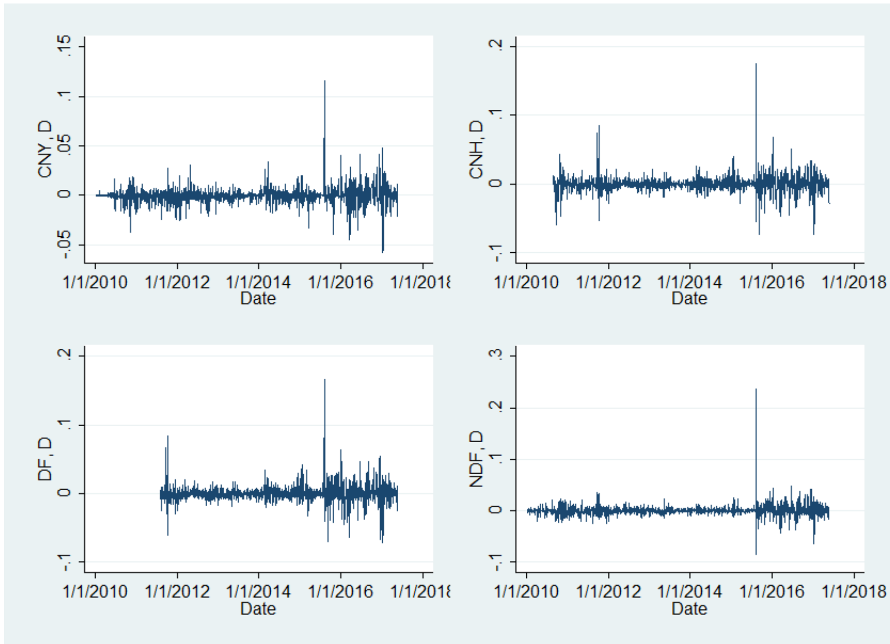
B.2 Figures

Figure B.1: Linkages Between Onshore Offshore Markets



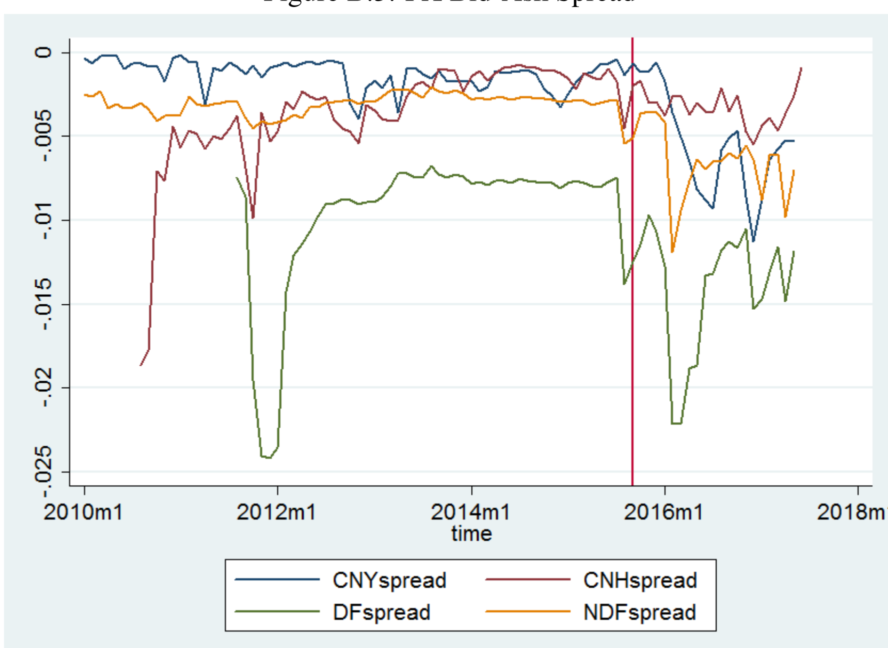
This paper modifies this figure from Rime and Schrimpf [2013]

Figure B.2: Onshore Offshore RMB Volatility



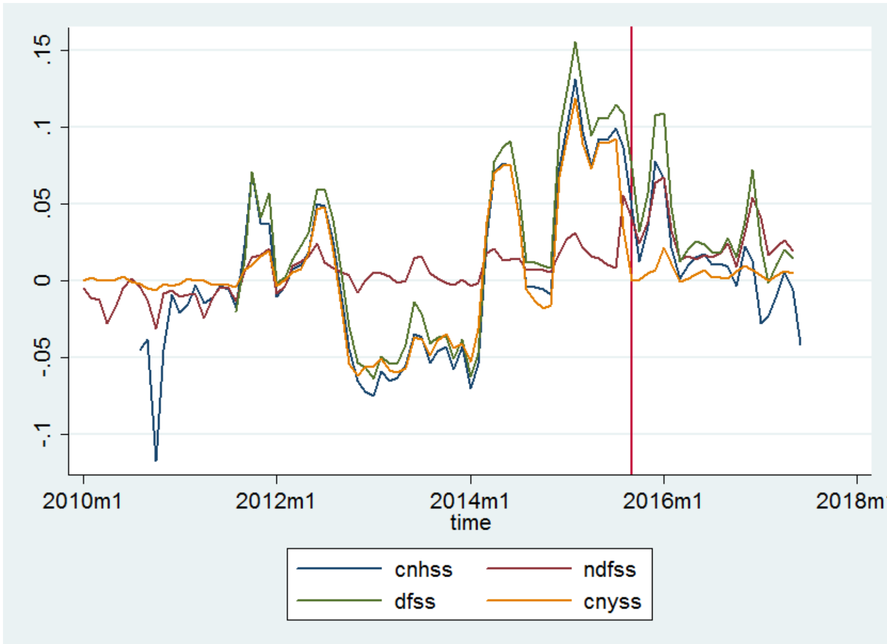
Source: Bloomberg Daily Basis

Figure B.3: FX Bid-Ask Spread



Source: Bloomberg Monthly Basis

Figure B.4: FX deviation from CPR



Source: Bloomberg Monthly Basis

B.3 Tables

Table B.1: Onshore and Offshore FX markets

	onshore FX markekt	offshore FX market
Products	Spot rate(CNY),Froward(DF),Swap Option and Swap premature	Spot rate(CNH) Forward(NDF)
Market Participants	PBoC, State-owned Bank, Subsidiaries of foreign banks Finance Corps	All qualified investors
Government intervention	Yes, Directly from CPR	Indirectly by State-owned Bank
Daily trading band	2% around CPR	No
Daily turnover in April 2013		
Spot	USD 20billion	USD 13.9 billion
Forward	USD 2.6billion	USD 8.4billion

* Note: Source: adjusted from Funke et al., daily turnover from Bloomberg

Table B.2: Summary Statistics(dejure index)

Variable	Mean	Std. Dev.	Min	Max	Obs
ka	0.7298	0.0623	0.6607	0.8571	2306
kai	0.6863	0.0776	0.6071	0.8571	2306
kao	0.7732	0.0506	0.7143	0.8571	2306
eqo	0.7366	0.1952	0.5000	1.0000	2306
eqoi	0.7308	0.1928	0.5000	1.0000	2306
eqoo	0.7423	0.2009	0.5000	1.0000	2306
eq_poi	0.6309	0.2199	0.5000	1.0000	2306
eq_poo	0.8307	0.2367	0.5000	1.0000	2306
bo	0.7713	0.1234	0.6250	1.0000	2306
boi	0.6847	0.1475	0.5000	1.0000	2306
boo	0.8580	0.1239	0.7500	1.0000	2306
bo_poi	0.5387	0.1336	0.5000	1.0000	2306
bo_poo	1.0000	0.0000	1.0000	1.0000	2306
mm	0.8847	0.0334	0.8750	1.0000	2306
mmi	0.7693	0.0668	0.7500	1.0000	2306
mmo	1.0000	0.0000	1.0000	1.0000	2306
mm_plbn	0.5387	0.1336	0.5000	1.0000	2306
mm_siln	1.0000	0.0000	1.0000	1.0000	2306
mm_pabr	1.0000	0.0000	1.0000	1.0000	2306
mm_siar	1.0000	0.0000	1.0000	1.0000	2306
de	0.8933	0.0442	0.8750	1.0000	2306
dei	1.0000	0.0000	1.0000	1.0000	2306
deo	0.7867	0.0885	0.7500	1.0000	2306
de_plbn	0.5734	0.1770	0.5000	1.0000	2306
de_siln	1.0000	0.0000	1.0000	1.0000	2306
de_pabr	1.0000	0.0000	1.0000	1.0000	2306
de_siar	1.0000	0.0000	1.0000	1.0000	2306

⋆ Note: Source: data that are generated in this paper.

Table B.3: Summary Statistics(hybrid index)

Variable	Mean	Std. Dev.	Min	Max	OBS
ka	0.831	0.045	0.784	0.953	2306
kai	0.693	0.081	0.622	0.915	2306
kao	0.969	0.032	0.916	0.994	2306
eqo	0.059	0.011	0.045	0.083	2306
eqoi	0.040	0.013	0.029	0.078	2306
eqoo	0.078	0.016	0.059	0.135	2306
eq_plbn	0.262	0.440	0.000	1.000	2306
eq_siln	0.661	0.473	0.000	1.000	2306
eq_pabr	1.000	0.000	1.000	1.000	2306
eq_siar	1.000	0.000	1.000	1.000	2306
bo	0.035	0.015	0.023	0.084	2306
boi	0.043	0.038	0.018	0.161	2306
boo	0.027	0.016	0.007	0.051	2306
bo_plbn	0.077	0.267	0.000	1.000	2306
bo_siln	1.000	0.000	1.000	1.000	2306
bo_pabr	1.000	0.000	1.000	1.000	2306
bo_siar	1.000	0.000	1.000	1.000	2306
mm	0.085	0.014	0.062	0.119	2306
mmi	0.088	0.029	0.052	0.170	2306
mmo	0.081	0.010	0.068	0.104	2306
mm_plbn	0.077	0.267	0.000	1.000	2306
mm_siln	1.000	0.000	1.000	1.000	2306
mm_pabr	1.000	0.000	1.000	1.000	2306
mm_siar	1.000	0.000	1.000	1.000	2306
dei	1.000	0.000	1.000	1.000	2306
deo	0.573	0.177	0.500	1.000	2306
de_plbn	0.147	0.354	0.000	1.000	2306
de_siln	1.000	0.000	1.000	1.000	2306
de_pabr	1.000	0.000	1.000	1.000	2306
de_siar	1.000	0.000	1.000	1.000	2306

* Note: Source: data that are generated in this paper.

Table B.4: Summary Statistics(weightednew index)

Variable	Mean	Std. Dev.	Min	Max	Obs
ka	0.8664	0.0382	0.8218	0.9515	2306
kai	0.7607	0.0661	0.7060	0.9145	2306
kao	0.9722	0.0230	0.9329	0.9906	2306
eqo	0.8488	0.1134	0.6674	0.9848	2306
eqoi	0.0528	0.0076	0.0425	0.0776	2306
eqoo	0.0844	0.0134	0.0672	0.1295	2306
eq_plbn	0.6309	0.2199	0.5000	1.0000	2306
eq_siln	0.8307	0.2367	0.5000	1.0000	2306
eq_pabr	1.0000	0.0000	1.0000	1.0000	2306
eq_siar	1.0000	0.0000	1.0000	1.0000	2306
bo	0.8617	0.0629	0.7507	0.9848	2306
boi	0.0602	0.0400	0.0261	0.1604	2306
boo	0.0239	0.0130	0.0071	0.0452	2306
w_boi	0.7962	0.0740	0.6680	0.9952	2306
w_boo	0.9271	0.0608	0.8333	0.9744	2306
bo_plbn	0.5387	0.1336	0.5000	1.0000	2306
bo_siln	1.0000	0.0000	1.0000	1.0000	2306
bo_pabr	1.0000	0.0000	1.0000	1.0000	2306
bo_siar	1.0000	0.0000	1.0000	1.0000	2306
mm	0.8847	0.0334	0.8750	1.0000	2306
mmi	0.1250	0.0274	0.0774	0.1703	2306
mmo	0.0813	0.0103	0.0679	0.1040	2306
mm_plbn	0.5387	0.1336	0.5000	1.0000	2306
mm_siln	1.0000	0.0000	1.0000	1.0000	2306
mm_pabr	1.0000	0.0000	1.0000	1.0000	2306
mm_siar	1.0000	0.0000	1.0000	1.0000	2306
de	0.8674	0.0695	0.7507	0.9848	2306
dei	0.0006	0.0013	0.0000	0.0065	2306
deo	0.0004	0.0006	0.0000	0.0025	2306
de_plbn	0.5734	0.1770	0.5000	1.0000	2306
de_siln	1.0000	0.0000	1.0000	1.0000	2306
de_pabr	1.0000	0.0000	1.0000	1.0000	2306
de_siar	1.0000	0.0000	1.0000	1.0000	2306
QDII	0.7814	0.1824	0.5000	0.9231	2306
QFII	0.8498	0.1447	0.5041	0.9857	2306

⋆ Note: Source: data that are generated in this paper.

Table B.5: Estimates of CID and risk factors(dejure index)

onshore	full sample	appreciation	depreciation
dejurenew	0.226***	0.201***	0.265***
	(0.01)	(0.02)	(0.04)
intervention	-0.002	-0.003	0
	0.00	(0.01)	0.00
factor	-0.016**	-0.018*	-0.01
	(0.01)	(0.01)	(0.01)
df_liq	1.527**	-5.310***	2.277*
	(0.65)	(1.09)	(1.35)
cny_liq	1.631**	-0.156	3.058**
	(0.76)	(0.47)	(1.39)
TED	1.500*	-2.149	2.903***
	(0.79)	(1.72)	(1.09)
cny_liq	0.374***	0.927***	-0.012
	(0.11)	(0.33)	(0.16)
cons	-0.167***	-0.140***	-0.194***
	(0.01)	(0.02)	(0.03)
N	2264	1133	1131
R2	0.281	0.322	0.192
F	71.406	34.246	15.719
R2_adj	0.279	0.317	0.187
offshore	full sample	appreciation	depreciation
dejurenew	0.061***	0.186***	-0.027
	(0.01)	(0.02)	(0.04)
intervention	0.012**	0.001	0.021***
	(0.01)	(0.01)	(0.01)
incyc	-0.006	0.015***	-0.021**
	0.00	0.00	(0.01)
NDFc	0.055	-5.426	0.013
	(0.13)	(3.77)	(0.14)
CNHc	0.146	-0.88	0.172
	(0.12)	(1.09)	(0.13)
TED	-3.265***	4.267***	-6.123***
	(0.83)	(1.23)	(1.29)
CNHdev	9.632***	8.411***	9.588***
	(0.19)	(0.21)	(0.31)
_cons	-0.032**	-0.168***	0.044
	(0.01)	(0.02)	(0.03)
N	2263	1132	1131
R-sq	0.888	0.892	0.868
F	492.304	445.823	289.086
R2_adj	0.887	0.891	0.867

* Note: The dependent variables are NDF CID and DF CID. This paper denotes *, **, and *** for significance at 0.10, 0.05 and 0.01 levels, respectively. The standard errors are in parentheses. ka represents the capital control index.

Table B.6: Estimates of CID and risk factors(hybrid index)

onshore	full sample	appreciation	depreciation
hybrid	0.170***	0.184***	0.144***
	(0.01)	(0.02)	(0.02)
intervention	-0.004	-0.008	-0.001
	0.00	(0.01)	0.00
factor	-0.015**	-0.015	-0.008
	(0.01)	(0.01)	(0.01)
df_liq	0.59	-6.916***	2.154*
	(0.42)	(1.09)	(1.24)
cny_kuq	0.943	-0.727	1.13
	(0.64)	(0.60)	(1.23)
TED	2.191***	-3.385**	3.475***
	(0.81)	(1.53)	(1.09)
cny_dev	0.508***	1.532***	0.016
	(0.12)	(0.32)	(0.15)
cons	-0.123***	-0.122***	-0.104***
	(0.01)	(0.02)	(0.02)
N	2264	1133	1131
R2	0.26	0.321	0.2
F	61.212	32.698	17.821
R2_adj	0.258	0.316	0.195
offshore	full sample	appreciation	depreciation
hybrid	0.028***	0.114***	-0.002
	(0.01)	(0.03)	(0.02)
intervention	0.012**	-0.002	0.021***
	(0.01)	(0.01)	(0.01)
factor	-0.007*	0.011**	-0.021*
	0.00	(0.01)	(0.01)
ndf_liq	0.059	-5.705	0.017
	(0.13)	(4.61)	(0.15)
cnh_liq	0.113	-3.033***	0.173
	(0.12)	(1.03)	(0.13)
TED	-3.470***	2.476*	-5.731***
	(0.87)	(1.26)	(1.31)
cnh_dev	9.568***	8.705***	9.643***
	(0.19)	(0.21)	(0.31)
cons	-0.005	-0.103***	0.023
	(0.01)	(0.03)	(0.02)
N	2263	1132	1131
R2	0.886	0.879	0.868
F	489.649	433.067	279.256
R2_adj	0.886	0.879	0.867

* Note: The dependent variables are NDF CID and DF CID. This paper denotes *, **, and *** for significance at 0.10, 0.05 and 0.01 levels, respectively. The standard errors are in parentheses. ka represents the capital control index.

Table B.7: Controls on outflow and inflow(dejure index)

onshore	full sample	appreciation	depreciation
dejurenew_kai	0.261***	0.276***	-0.243***
	(0.021)	(0.029)	(0.038)
dejurenew_kao	-0.014	-0.061**	-0.055
	(0.019)	(0.03)	(0.074)
intervention	-0.004	-0.008*	0
	(0.003)	(0.004)	(0.003)
factor	-0.007	-0.009	-0.004
	(0.007)	(0.009)	(0.007)
df_liq	0.558	-6.361***	-1.978*
	(0.369)	(1.037)	(1.148)
cny_liq	-0.266	-0.893	-1.02
	(0.525)	(0.65)	(1.894)
TED	3.423***	-0.738	-3.667***
	(0.744)	(1.584)	(1.053)
cny_dev	0.526***	1.479***	-0.084
	(0.108)	(0.388)	(0.146)
cons	-0.182***	-0.144***	-0.134***
	(0.01)	(0.022)	(0.04)
N	2264	1133	-1131
R2	0.304	0.348	-0.21
F	87.208	38.384	-19.747
R2_adj	0.302	0.343	-0.204
offshore	full sample	appreciation	depreciation
dejurenew_kai	-0.050**	0.007	-0.01
	(0.022)	(0.033)	(0.028)
dejurenew_kao	0.102***	0.161***	-0.019
	(0.019)	(0.025)	(0.042)
intervention	0.013***	0.002	-0.021***
	(0.005)	(0.005)	(0.005)
factor	-0.010**	0.010**	-0.021**
	(0.004)	(0.004)	(0.011)
ndf_liq	0.288*	-3.502	-0.003
	(0.15)	(3.071)	(0.178)
cnh_liq	0.371***	-0.311	-0.157
	(0.143)	(1.11)	(0.162)
TED	-4.426***	3.063**	-6.087***
	(0.923)	(1.325)	(1.284)
cnh_dev	9.613***	8.425***	-9.587***
	(0.185)	(0.215)	(0.31)
cons	-0.026**	-0.154***	-0.046
	(0.013)	(0.021)	(0.034)
N	2263	1132	-1131
R2	0.889	0.894	-0.868
F	460.897	444.7	-254.355
R2_adj	0.889	0.893	-0.867

* Note: this table reports the estimated coefficients of Eq.(12.3). This paper denotes *, **, and *** for significance at 0.10, 0.05 and 0.01 levels, respectively. The standard errors are in parentheses, reported in parenthesis.

Table B.8: Controls on outflow and inflow(hybrid index)

onshore	full sample	appreciation	depreciation
hybrid_kai	0.202***	0.160***	-0.124*
	(0.022)	(0.047)	(0.067)
hybrid_kao	0.030**	0.026	-0.061***
	(0.012)	(0.05)	(0.018)
intervention	-0.005*	-0.007	-0.001
	(0.003)	(0.005)	(0.003)
factor	-0.009	-0.016*	-0.006
	(0.007)	(0.009)	(0.007)
df_liq	0.561	-6.471***	-2.127*
	(0.372)	(1.079)	(1.21)
cny_liq	-0.694	-0.6	-0.194
	(0.491)	(0.576)	(1.729)
TED	2.402***	-3.007*	-3.940***
	(0.807)	(1.636)	(1.021)
cny_dev	0.321**	1.258***	-0.026
	(0.126)	(0.441)	(0.151)
cons	-0.156***	-0.109***	-0.131***
	(0.01)	(0.022)	(0.035)
N	2264	1133	-1131
R2	0.277	0.323	-0.201
F	67.068	39.473	-17.517
R2_adj	0.274	0.318	-0.196
offshore	**full sample**	**appreciation**	**depreciation**
hybrid_kai	0.134***	0.353***	-0.044
	(0.021)	(0.031)	(0.044)
hybrid_kao	-0.046***	-0.240***	-0.011
	(0.012)	(0.03)	(0.015)
intervention	0.012***	0.003	-0.021***
	(0.004)	(0.004)	(0.005)
factor	-0.001	0.006	-0.019*
	(0.004)	(0.005)	(0.01)
ndf_liq	-0.225	-1.626	-0.077
	(0.138)	(2.509)	(0.176)
cnh_liq	-0.104	-0.887	-0.084
	(0.124)	(1.004)	(0.159)
TED	-3.070***	3.550***	-5.322***
	(0.854)	(1.244)	(1.262)
cnh_dev	9.356***	8.137***	-9.609***
	(0.188)	(0.231)	(0.314)
cons	-0.036***	-0.031	-0.001
	(0.011)	(0.025)	(0.025)
N	2263	1132	-1131
R2	0.89	0.899	-0.868
F	445.602	518.599	-243.613
R2_a	0.889	0.898	-0.867

* Note: this table reports the estimated coefficients of Eq.(12.3). This paper denotes *, **, and *** for significance at 0.10, 0.05 and 0.01 levels, respectively. The standard errors are in parentheses, reported in parenthesis.

Table B.9: dejure GARCH(onshore)

onshore	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Main Equation							
ϕ_1	0.856***	0.860***	0.874***	0.871***	0.850***	0.857***	0.885***
	(-0.005)	(-0.005)	(-0.006)	(-0.004)	(-0.005)	(-0.005)	(-0.006)
μ	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Variance Equation							
weightednew	-0.307						3.525***
	(-0.933)						(-0.551)
intervention		-297.593***					-1.253***
		(-1.29)					(-0.334)
concyc			1.562***				1.674***
			(-0.2)				(-0.139)
TED				824.095***			736.495***
				(-39.833)			(-27.976)
df_liq					-549.620***		-373.296***
					(-26.2)		(-23.894)
cny_dev						-12.422	-53.923***
						(-10.16)	(-6.894)
ω	-10.270***	-9.728***	-10.166***	-12.468***	-10.306***	-10.143***	-15.005***
	(-0.773)	(-0.081)	(-0.099)	(-0.177)	(-0.095)	(-0.115)	(-0.484)
ARCH							
α_1	0.692***	0.731***	0.701***	0.684***	0.578***	0.706***	0.447***
	(-0.038)	(-0.036)	(-0.036)	(-0.037)	(-0.032)	(-0.038)	(-0.025)
β_1	0.282***	0.156***	0.206***	0.182***	0.170***	0.235***	0.038***
	(-0.023)	(-0.019)	(-0.02)	(-0.017)	(-0.02)	(-0.021)	(-0.01)
N	1810	1839	1839	1839	1839	1839	1810
logL	4859.288	4960.121	4963.794	5018.052	5010.201	4949.828	5054.084
chi2	2.70E+04	2.80E+04	1.90E+04	3.80E+04	2.80E+04	2.80E+04	1.90E+04

Table B.10: dejure GARCH(offshore)

offshore	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Main Equation							
ϕ_1	0.991***	0.990***	0.990***	0.991***	0.990***	0.987***	0.989***
	(-0.003)	(-0.003)	(-0.004)	(-0.003)	(-0.004)	(-0.003)	(0.003)
μ	0	0	0	0	0	0	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
HET							
weightednew	0.202						2.617***
	(-0.532)						(0.994)
intervention		-0.178					-0.351
		(-0.421)					(0.298)
concyc			-0.918***				-0.802***
			(-0.173)				(0.138)
ndf_liq				-95.580***			-55.355***
				(-8.156)			(10.284)
TED					-89.099**		-79.596***
					(-37.2)		(10.555)
cnh_dev						55.739***	49.584***
						(-5.476)	(3.507)
ω	-9.929***	-9.775***	-9.585***	-9.687***	-9.502***	-9.765***	-11.590***
	(-0.438)	(-0.124)	(-0.093)	(-0.088)	(-0.15)	-0.123	(0.853)
ARCH							
α_1	0.498***	0.491***	0.502***	0.409***	0.486***	0.470***	0.354***
	(-0.038)	(-0.039)	(-0.038)	(-0.034)	(-0.039)	(-0.040)	(0.031)
β_1	0.210***	0.221***	0.170***	0.124***	0.218***	0.201***	0.053
	(-0.045)	(-0.047)	(-0.04)	(-0.04)	(-0.047)	(-0.046)	(0.034)
N	1809	1838	1838	1838	1838	1838	1838
logL	5268.55	5355.635	5362.727	5402.592	5356.72	5374.374	5448.339
chi2	8.10E+04	8.20E+04	7.90E+04	9.90E+04	7.80E+04	1.00E+05	1.0e+05

Table B.11: hybrid GARCH(onshore)

onshore	(1)	(2)	(3)	(4)	(5)	(6)
Main Equation						
ϕ_1	0.841***	0.860***	0.874***	0.850***	0.871***	0.857***
	(-0.006)	(-0.005)	(-0.006)	(-0.005)	(-0.004)	(-0.005)
μ	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Variance Equation						
hybrid	-47.180***					
	(-14.825)					
intervention		-297.593***				
		(-1.29)				
concyc			1.562***			
			(-0.2)			
TED				-549.620***		
				(-26.2)		
df_liq					824.095***	
					(-39.833)	
cny_dev						-12.422
						(-10.16)
ω	24.696**	-9.728***	-10.166***	-10.306***	-12.468***	-10.143***
	(-10.473)	(-0.081)	(-0.099)	(-0.095)	(-0.177)	(-0.115)
ARCH						
α_1	0.477***	0.731***	0.701***	0.578***	0.684***	0.706***
	(-0.029)	(-0.036)	(-0.036)	(-0.032)	(-0.037)	(-0.038)
β_1	0.448***	0.156***	0.206***	0.170***	0.182***	0.235***
	(-0.016)	(-0.019)	(-0.02)	(-0.02)	(-0.017)	(-0.021)
N	1839	1839	1839	1839	1839	1839
logL	4962.18	4960.121	4963.794	5010.201	5018.052	4949.828
chi2	2.10E+04	2.80E+04	1.90E+04	2.80E+04	3.80E+04	2.80E+04

Table B.12: hybrid GARCH(offshore)

offshore	(1)	(2)	(3)	(4)	(5)	(6)
Main Equation						
ϕ_1	0.988***	0.990***	0.990***	0.991***	0.990***	0.987***
	(-0.003)	(-0.003)	(-0.004)	(-0.003)	(-0.004)	(-0.003)
μ	0	0	0	0	0	0
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Variance Equation						
hybrid	-9.031***					
	(-0.708)					
intervention		-0.178				
		(-0.421)				
concyc			-0.918***			
			(-0.173)			
TED				-95.580***		
				(-8.156)		
ndf_liq					-89.099**	
					(-37.2)	
cnh_dev						55.739***
						(-5.476)
ω	-2.217***	-9.775***	-9.585***	-9.687***	-9.502***	-9.765***
	(-0.548)	(-0.124)	(-0.093)	(-0.088)	(-0.15)	(-0.123)
ARCH						
α_1	0.420***	0.491***	0.502***	0.409***	0.486***	0.470***
	(-0.034)	(-0.039)	(-0.038)	(-0.034)	(-0.039)	(-0.039)
β_1	0.137***	0.221***	0.170***	0.124***	0.218***	0.201***
	(-0.043)	(-0.047)	(-0.04)	(-0.04)	(-0.047)	(-0.046)
N	1838	1838	1838	1838	1838	1838
logL	5380.133	5355.635	5362.727	5402.592	5356.72	5374.374
chi2	9.70E+04	8.20E+04	7.90E+04	9.90E+04	7.80E+04	1.00E+05

Appendix C

Part 3 Appendices

C.1 Daily capital control index

The daily capital control index is calculated by the unweighted average index of following financial related categories in order to reflect the sensitivity of capital control policy changing. For each following financial related category, the index is between 1 and 0 where 1 means totally controlled and 0 vice versa (4th Jan 2010 is a benchmark date). If there is a policy change from full control to semi-open, the index becomes 0.5 from 1. Also, the index would be unchanged, if there is not a new released policy. The novel capital control index of China on a daily basis from 2010 to 2018 is based on the public information provided from SAFE website and PBoC annual policy reports.

C.2 Koyck model derivation

Substitute $\delta_i = \delta_0 \lambda^i$ into $Y_t = \beta_0 + \delta_0 X_t + \delta_1 X_{t-1} + \delta_2 X_{t-2} + \ldots + \delta_q X_{t-q} + \ldots + u_t$, and lag one period:

$Y_{t-1} = \beta_0 + \delta_0 X_{t-1} + \delta_0 \lambda X_{t-2} + \delta_0 \lambda^2 X_{t-3} + \ldots + \delta_0 \lambda^q X_{t-q-1} + \ldots + u_{t-1}$

then multiply both sides of above equation by λ:

$\lambda Y_{t-1} = \lambda \beta_0 + \delta_0 \lambda X_{t-1} + \delta_0 \lambda^2 X_{t-2} + \delta_0 \lambda^3 X_{t-3} + \ldots + \delta_0 \lambda^{q+1} X_{t-(q+1)} + \ldots + \lambda u_{t-1}$

then use original equation minus this new equation:

$Y_t - \lambda Y_{t-1} = (1-\lambda)\beta_0 + \delta_0 X_t + u_t - \lambda u_{t-1}$

estimate the model:

$Y_t = \beta^* + \lambda Y_{t-1} + \delta_0 X_t + u_t^*$

where $\beta^* \equiv (1-\lambda)\beta_0$ and $u_t^* \equiv u_t - \lambda u_{t-1}$.

Therefore,

$$LRP = \sum_{i=0}^{n} = \frac{\partial Y_t}{\partial X_{t-i}} = \sum_{i=0}^{n} \delta_i = \sum_{i=0}^{n} \delta_0 \lambda^i = \frac{\delta_0}{1-\lambda}$$

C.3 IRFs

Figure C.1: Monetary policy - changed reserve ratio $\varepsilon_c \downarrow$

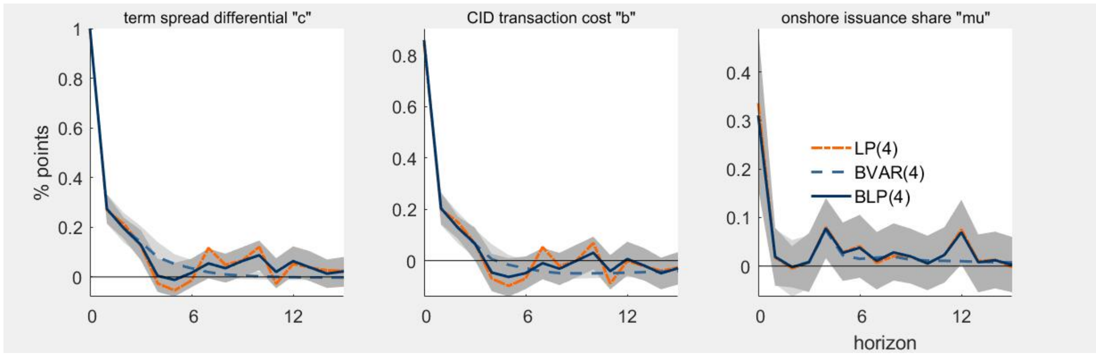


Figure C.2: Investor preference - stock market substitution effect $\varepsilon_c \downarrow$

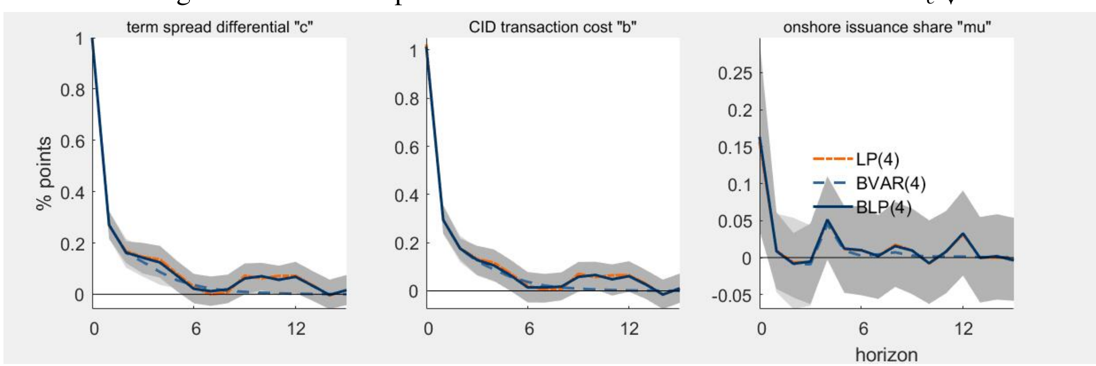


Figure C.3: Money market regulatory - reverse REPO of open market $\varepsilon_c \downarrow$

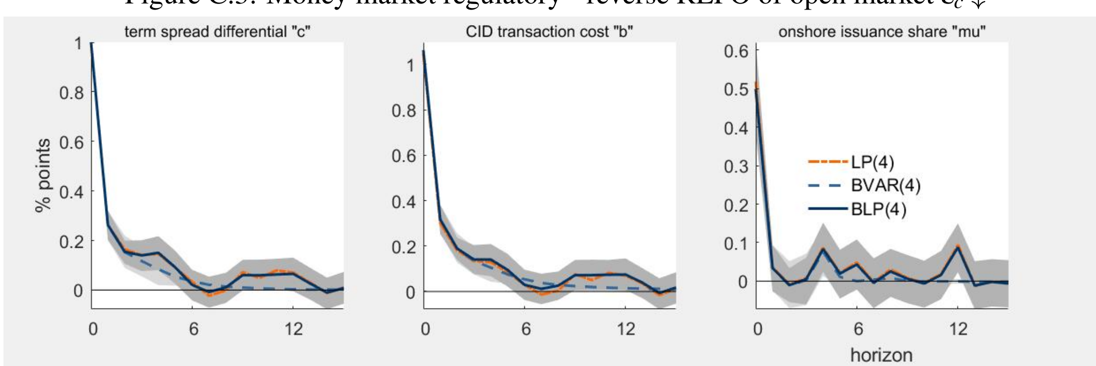


Figure C.4: Central bank policy - liquidity of currency market $\varepsilon_b \downarrow$

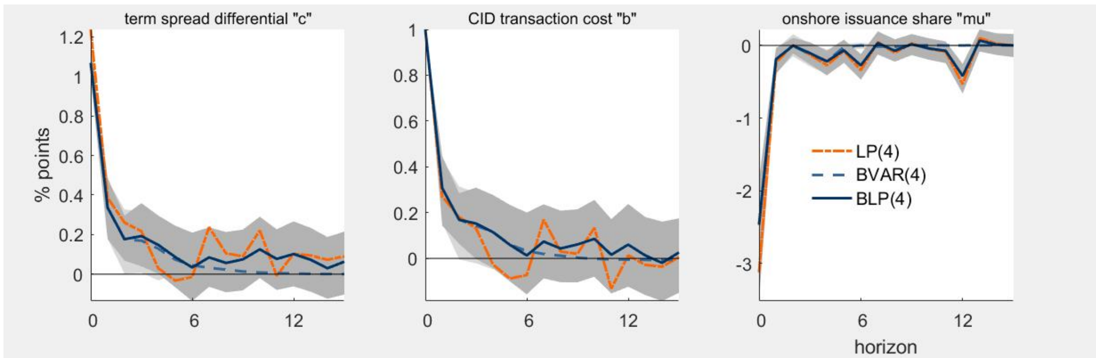


Figure C.5: Trader expectation - volatility of currency market $\varepsilon_b \downarrow$

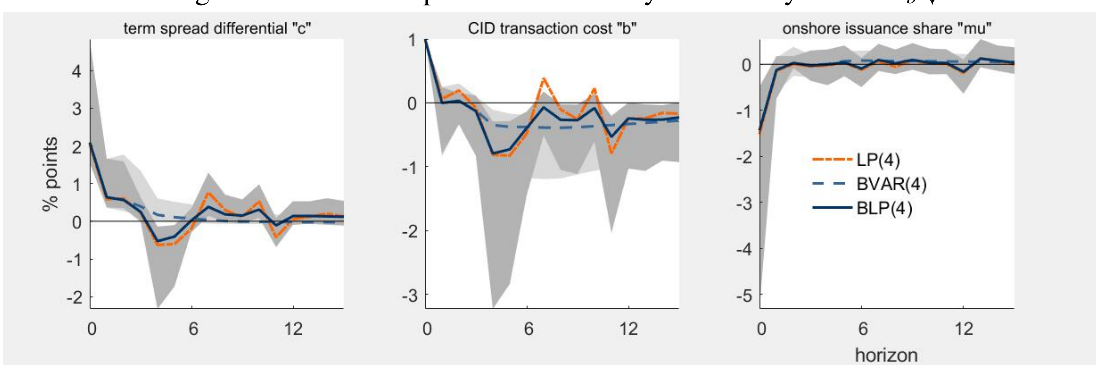


Figure C.6: Currency market regulatory - capital control $\varepsilon_b \downarrow$