Carry Trade Dynamics under Capital Controls:

The Case of China

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Abstract

Despite an attractive interest rate differential between China and foreign countries, existing capital control might prevent currency carry trade strategies to be executed. We focus on the copper market to study if trades are taken in order to execute carry trade strategies. We find that copper value is related to carry trade through the onshore-offshore interest differential, while the pegged nature of the USD/CNY exchange rate makes traders indifferent to the forward risk premium. We rule out the possibility of high average payoff due to peso problems, because risk factors are insignificant, implying that carry traders are either fully hedged on FX risks, or they are unconcerned about FX risks.

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1 Introduction

A carry trade is a transaction between countries where an investor borrows in low interest rate currencies and invests in high interest rate currencies. According to uncovered interest parity (UIP) theory, this strategy would not be profitable. Under the assumption of risk neutrality and rational expectations, indeed, the high-interest-rate currency should depreciate enough to remove gains. However, empirical studies consistently argue against UIP, by providing evidence that high interest rate currencies have the opposite tendency to appreciate and low interest rate currencies tend to depreciate, which is also known as the forward premium puzzle (Hansen and Hodrick, 1980; Fama, 1984). Several papers have empirically tested the violation of UIP, finding persistent excess carry trade returns across developed and developing countries (Bansal and Dahlquist, 2000; Flood and Rose, 2002; Chinn and Meredith, 2005; Chaboud and Wright, 2005; Darvas, 2009). A stream of literature has focused on explaining carry trade returns as foreign exchange (FX) risk compensations (Heath et al., 2007; Burnside et al., 2010; Lustig, Hanno and Roussanov, Nikolai and Verdelhan, Adrien, 2011; Menkhoff et al., 2012). Additional research has reported that the carry trade can be executed within common currency areas with differing risk profiles of sovereigns (Acharya and Steffen, 2015). A primary assumption of the carry trade is that it takes place in free international capital markets, where investors can trade financial assets in a near instantaneous manner.

A very interesting research question is what happens to less financially open economies, characterised by capital controls? We contribute to the carry trade research stream by incorporating capital controls into the carry trade analysis, linking shadow capital flows to unofficial channels, like commodity trading. Chen et al. (2010) demonstrate that "commodity currency" exchange rates have remarkably robust power in predicting future global commodity prices, both in-sample and out-of-sample due to the different nature of the two variables, i.e. backward looking versus forward looking.[1]

Our paper specifically focuses on China showing which mechanism exists to execute the carry trade when capital controls take place. We study how firms profit from substituting trade factors under an asymmetric currency control regime, where foreign exchange current account trades are relatively free but trade in capital is strictly regulated. We focus on how firms seek to execute currency trades via the less regulated current account market in the quasi-financial asset of copper stock, but subsequently use the revenue as capital account holdings. Through analysing copper stock holdings in Shanghai, we track those activities and their relationship to onshore-offshore interest rate differentials.

We provide evidence that due to the nature of the exchange rate between Chinese yuan (CNY) and United States dollar (USD), variation in the exchange rate cannot explain changes in copper value. We show that carry trade can explain copper value. We observe that copper stock in China is driven by carry trade activities. We report causality running from carry trade returns to copper holdings, but that copper is only used as a medium to facilitate the carry trade and does not impact carry trade returns. Carry trade affects copper value in the long run through the onshore-offshore interest differential, with the onshore interest rate driving up the copper price. Given that the USD/CNY exchange rate is pegged, neither the spot nor forward rate affects copper. However, expectations of RMB depreciation impacts copper value in the near future, as does the onshore-offshore interest differential.

High average payoffs to the carry trade might be also due to the existence of a peso problem. We rule out such a possibility, since we report that the risk profile of the strategy, proxied by the 1-month FX option implied volatility in percentage, does not affect trading behaviour due to the specific features of the Chinese markets. Traders profit from carrying policy hedged-financially unhedged position due to the quasi-fixed exchange rate operated by

[1] The theoretical channels apply to countries that vastly import commodity products, not just nations that heavily export. That is, commodity price fluctuations may induce exchange rates movements (in the opposite direction) for large commodity importers.

the People's Bank of China (PBOC). The non-technical but quasi-fixed nature of CNY makes the strategy reasonable, even if unhedged.

The remainder of the paper is structured in the following way. Section 2 provides the rationale of the focus on copper trade financing. Section 3 describes how the commodity carry trade works for both covered and uncovered carry trade strategy, identifying the cash flows and the key factors. Data and empirical analysis are presented in Section 4. Section 5 concludes with final remarks.

2 Capital Controls and Copper

Although China has relaxed restrictions on current account transactions to promote trade in goods and services since 1996, it has maintained a tight grip on capital account transactions. Foreign direct investment (FDI) and trade finance have been largely liberalized, while portfolio investment, money market, and financial derivative transactions remain strictly regulated (Prasad and Wei, 2007; Zhang, 2014). Such measures are intended to protect the country from international financial volatility and risks. Through controlling capital inflows, in theory, overheating in financial markets and the economy due to excessive flow of foreign capital is restrained: whereas capital flights can be kept within certain limits by controls on capital outflows. However, such capital measures are not watertight as shown by Ma and McCauley (2008). While capital account transactions are closely monitored by the State Administration of Foreign Exchange of China (SAFE), firms still find ways to evade them.

Over-invoicing and commodity trade finance—the financing of the physical trade (purchase and sale) in commodities—are two possible ways to avoid capital controls. Due to the widening onshore-offshore interest rate spreads, the latter has grown quickly and become the most popular tool for carry trade activities.

Figure 1 shows the behaviour of the 1-month China inter-bank offering rate (CHIBOR) and the 1-month US Dollar (USD) London inter-bank offering rate (LIBOR) from January 2003 to

February 2017. The persistent differential between the two rates suggests attractiveness for profitable carry trade strategies. Over the entire post-crisis period, the onshore offshore interest rate difference, given by the gap between the two rates, stays consistently positive, averaging 344 basis points from January 2009 to December 2016.

At the same time, despite a strict capital account system, the long-standing presence of net errors and omissions (E&O) in the balance of payments (BoP) might suggest capital flights. Moreover, persistent discrepancies in the foreign direct investment (FDI) and capital account support the view that capital flows are moving via unregulated channels.

[INSERT FIGURE 1 HERE]

Due to policy arbitrage between the relatively free current account and the heavily regulated capital account, commodity trade financing proves to be a flexible tool for carry trade activities. Companies involved in commodity trading usually have a professional trading desk and a research team, whose buy-side expertise allows them to profit from risk-free interest rate differentials between markets. Moreover, commodities, while considered trade in goods and services under the current account, have the ability to act as a quasi-capital asset with a clear regularly updated market price that allows them to act as collateral better than other assets.

Among all types of commodities, we are interested in studying copper for a dual reason. First, copper is the most preferred metal underlying commodity trade financing due to its durability and function as a store of value. Second, the restrictions on copper import and export are less, compared to precious metals, such as gold and silver.

Figure 2 compares the London Metal Exchange (LME), the Commodity Exchange (COMEX), a division of the New York Mercantile Exchange (NYMEX), and the Shanghai Futures Exchange (SHFE), with Shanghai inventory increasing from 4% of global stock in 2009 to 38% in 2014.[2] Even if copper has a significant industrial use, over the same period, the industrial production

[2] Sources: Bloomberg, Wind, SHFE, LME and COMEX.

does not seem to show evidence of a drastic change that requires such a large supporting change in inventory.

[INSERT FIGURE 2 HERE]

3 Commodity Carry Trade

We assume three parties are involved: an onshore carry trader (company A) with an offshore subsidiary (company A'), a copper owner (company B) and the bank that provides a letter of credit (bank C) with a branch C' acting as an offshore low interest rate credit provider. The transaction begins when A and B enter a contract to import copper from an offshore company B (step 1). At the same time, company A, with the contract in hand, obtains a letter of credit (L/C), issued at the offshore USD interest rate, from onshore bank C (step 2). Company A usually deposits a lump-sum between 20% and 30% of the notional amount of the L/C as margin. Copper is stored in a warehouse in free trade zone, without entering customs, exempted from duties and fees before customs declaration. Party A and B exchange L/C and copper warrant at price P (step 3). The onshore party A re-exports the copper to the offshore party A' and receives USD (step 4). The transaction is fulfilled by sending the warrant documentation, without moving physical copper in a bonded warehouse offshore. At the same time, the offshore party A' pays the onshore copper seller A in USD or offshore CNY. [3] By proving that the copper sale under current account regulations is a normal trade, the onshore bank C would convert USD or offshore CNY into onshore in compliance with SAFE regulation (step 5). Company A invests in the Chinese stock market, receiving as return the onshore interest rate (step 6). Next, the offshore party A' gives the copper warrant back to B at a discount c for assisting A in the transaction (step 7). The copper seller B presents L/C to the offshore branch C' and receives an amount equal to the copper value (step 8). Finally, company A pays back USD to bank C at the offshore rate.

[3] Note that we have assumed that A owns A', making step 4 as an "arm length transaction". Without loss of generality, we may also develop a scenario where A' is an offshore company, independent from A, the trade might rotate several times during the L/C period or leverage may be used, etc.

Figure 3 displays the various steps implemented in the process. Blue and orange boxes indicate the onshore and offshore markets, respectively.

[INSERT FIGURE 3 HERE]

Copper trade financing deals are generally subject to onshore and offshore risk-free interest rates, FX spot rates, risk for uncovered trades, forward premium for covered trades, transaction costs and taxes.

The return of the 1-month covered carry trade is equal to:

$$R_t^c = \frac{S_t(1+i_t^{on})}{F_t} - (i_t^{off} + 1 + c),, \tag{1}$$

where R_t^c is the covered carry trade return, S_t is the USD/CNY spot exchange rate, F_t is the USD/CNY 1-month forward rate, i_t^{on} is the onshore 1-month risk-free interest rate, i_t^{off} is the offshore 1-month risk-free interest rate, and c is the discount rate.[4,5]

Equation (1) demonstrates how the covered carry trade return is driven by the USD/CNY spot rate, USD/CNY forward rate, onshore risk-free interest rate, and offshore risk-free interest rate. All factors are fixed at inception, effectively hedging the carry trade return. Traders are, indeed, profiting from carrying policy hedged-financially unhedged position due to the quasi-fixed exchange rate operated by the PBOC. [6]

Moreover, the onshore-offshore interest rate differential and CNY appreciation/depreciation expectation in the forward market affects the carry trade return at inception. Given the effective fixed rate of the USD/CNY and the low volatility of short-term interest rate differentials, this provides a low risk well-hedged return with traders are profiting from

[4] We look at profitability of the 1-month carry trade return as a proxy for overall carry trade return profitability (Burnside et al., 2010; Lustig, Hanno and Roussanov, Nikolai and Verdelhan, Adrien, 2011).

[5] In the following sections, we consider c as negligible.

[6] This has been referred to in the literature as a "crude investment strategy", though, given the nontechnical but quasi-fixed nature of the RMB, an unhedged currency strategy in this case may be reasonable (Jordà and Taylor, 2012).

peso problems, i.e. low-probability events. [7,8,9]

Traders willing to exploit fluctuations in the FX market pursue, instead, an uncovered carry trade strategy. Cash flows are similar, with the only difference being that traders do not hedge in the uncovered carry trade strategy: the spot exchange at time t+1, S_{t+1}, replaces F_t.

The 1-month uncovered carry trade is given by:

$$R_t^u = \frac{S_t(1+i_t^{on})}{S_{t+1}} - (i_t^{off} + 1 + c), . \tag{2}$$

As shown by Equation (2), the uncovered carry trade return is not determined at inception, but at maturity t + 1. Carry traders do not enter the forward market to hedge themselves against fluctuations in the FX market. As a result, the uncovered strategy profit and loss is affected by the fluctuations in the FX rate during the holding period while the covered strategy is not.

4 Empirical Analysis

4.1 Data and Variables

We use data from China copper raw material output monthly data to proxy for domestic copper consumption. Copper raw material is upper-stream to car production, home appliance production, electric wire and other productions. We use copper stock value in Shanghai Futures Exchange as proxy for copper carry trade positions outstanding. We use Shanghai Futures Exchange Copper Stock Total Deliverable, reported by Shanghai Futures Exchange and

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[7] See Burnside et al. (2010) for a more details on peso problems and carry trade.

[8] In our framework, traders are assumed to be hedged by the quasi-fixed exchange rate. They are indeed executing the carry trade in USD as compared to EUR due to the fact that they do not need to hedge foreign exchange risk. Executing the carry trade between USD and RMB, indeed, provides an implicit currency hedge

[9] Since we focus on a single economy, we do not investigate the benefits of diversification in the carry trade as in Burnside et al. (2008).

collected by Bloomberg weekly from June 5, 2003 to February 23, 2017. The copper value (COPPER) is calculated as total copper stock in USD (thousands). The 1-month onshore risk-free interest rate is given by the CHIBOR, while the 1-month offshore risk-free interest rate is proxied as the 1-month USD LIBOR.[10] We use USD/CNY spot rate (SPOT) and USD/CNY 1-month forward rate (FWD) as exchange rates. We choose USD/CNY 1-month option implied volatility (VOL) to proxy for FX rate risk.[11] We obtain our data from Wind and Bloomberg. We also report statistics for the onshore-offshore interest rate differential (ID) and the forward premium (FP). Our final sample is composed of 717 weekly observations from January 1, 2003 to February 23, 2017. Table 1 reports the descriptive statistics for our sample. The covered carry trade return (CCR) is given by Equation (1), while ID and FP identify the interest-rate differential and the forward premium, respectively.

[INSERT TABLE 1 HERE]

4.2 Empirical Analysis

As a first step, we want to determine if there is long-run relationship between copper and carry trade, and if so, whether copper value is driven by carry trade or vice versa. We implement the Johansen test for cointegration since both variable are first-order integrated (I(1)). We detect the existence of a cointegration relationship between the two variables.[12] Panel A in Table 2 reports the normalized cointegrated vector estimates, implying a positive relationship between copper and carry trade as shown by the negative sign of CCR. Given the existence of a cointegration relationship, we make use of a vector error correction model (VECM) of order 4—based on information criteria—. Due to the existence of a cointegrating

[10] Unreported results make use of Shanghai Interbank Offering Rate (SHIBOR), as 1-month onshore risk-free rate, first quoted on October 8, 2006, and officially introduced on January 4, 2007. For the pre-SHIBOR era, we use the weighted-average interbank lending rate. The two rates follow the same path after SHIBOR is introduced.

[11] The average storage cost per ton is 36.7 cents USD per ton per day. For a 30-day contract, this represent approximately 0.2% of the asset value or approximately 2.47%. Given the rapid turnover and implied leverage, we can exclude storage costs without affecting our final results.

[12] Trace statistic, the Schwarz information criterion (SBIC) and the Hannan-Quinn information criterion (HQIC) identify at most one cointegration equation.

vector, we make use of a vector error correction model (VECM) representation of order 4 — based on information criteria—to analyze short run changes in variables and deviations from equilibrium. The VECM estimates are shown in Table 3, Panel B, Column (1). The error correction term suggests the speed of adjustment to long-run equilibrium for copper value is 2.3%, i.e., 2.3% of disequilibrium from the long run equilibrium is corrected within one period. Then, we look at the carry trade return coefficients. Changes in covered carry trade return take one week to make a significant effect on copper trade finance. With bootstrapped standard errors, as in Column (2), even changes in covered carry trade from the previous month affect copper trade finance. We also observe the direction of Granger-causality between COPPER and CCR using the TodaYamamoto (TY) causality test and discover that causality runs from covered carry returns to copper stock value. At the same time, there is no causality running from copper value to covered carry trade return. There is no effect from outstanding carry trade positions to the covered carry trade return, since carry trade returns are driven by interest rate differentials and foreign exchange risk rather than copper. Moreover, the size of copper collateral deals is not sufficient to move currency or interest prices and arbitrage away
profitability.[13]

[INSERT TABLE 2 HERE]

Figure 4 shows the orthogonalized impulse response functions of the model within ten periods in order to analyse the dynamic relationship between covered carry trade and copper value. A positive shock in covered carry trade return leads to a slow and steady increase in copper stock value over the entire period. Vice versa, when shocking copper value, we report a subtle negative effect that decays slowly with time, supporting the view that the value of copper might not cause carry trade return.

[13] Causality from CCR to COPPER has a χ^2 statistic of 14.10, while it is 7.50 when looking in the opposite direction.

[INSERT FIGURE 4 HERE]

By using quarterly data for Australia, Canada, Chile, New Zealand and South Africa, Chen et al. (2010) investigates the dynamic relationship between commodity price movements and exchange rate fluctuations and find that exchange rates are very useful in forecasting future commodity price. In light of that, we run a multivariate regression to see if variations in the USD/CNY spot rate can explain changes in copper value in our setting.

Table 3 reports the regression results for our multivariate analysis. Column (1) assumes that copper follows an autoregressive model (AR) of order 3. In Column (2), the autoregressive model has bootstrapped errors. In Columns (3) and (4), we include the USD/CNY exchange rate as explanatory variables. Individual coefficients on exchanges are statistically not significant and the adjusted R-squared decreases. This suggests that there is no gain by adding changes in the exchange rates as additional explanatory variable.

[INSERT TABLE 3 HERE]

Figure 5 plots the historical changes in the USD/CNY spot rate over the period 2003 to 2015. The plot shows negligible changes in the exchange rate, supporting the main findings of Table 3.

[INSERT FIGURE 5 HERE]

Once established that the copper value is not affected by changes in the spot rate, we turn to the relationship between carry trade and copper once more and build two tiers of modelling to decompose the factors that determine carry trade profit, loss and risks. Figure 6 shows the decomposition of the sources of carry trade exposure, depending on hedging the FX risks.

[INSERT FIGURE 6 HERE]

Carry traders' profits and losses are determined by three factors: onshore-offshore interest rate difference; FX forward premium; and FX market volatility. The first two factors drive return, while the last one is concerned with risk. As a first-tier decomposition of carry trade return, we model to discover how copper carry trade positions react to these three factors. Specifically, we are interested in how the onshore-offshore interest rate differential (ID), USD/CNY forward premium (FP), and changes in USD/CNY FX option implied volatility (IMV) affect copper. Since unit root tests suggest a mix between $I(0)$ and $I(1)$ variables, we make use of an autoregressive distributed lag (ARDL) model to explore the link between copper value and carry trade:[14]

$$CV_t = \alpha_0 + \mathrm{X}\beta_i CV_{t-i} + \mathrm{X}\gamma_j FP_{t-j} + \mathrm{X}\delta_k ID_{t-k} + \mathrm{X}\theta_l IMV_{t-l} + \varepsilon_{t}, \quad (3)$$

We test the long-run relationship among the variables. Bounds testing suggest the existence of a long-term relationship between copper stock value, forward premium, and interest rate differentials.[15] The long-run relationship suggests that capital control is consistent with copper trade finance as a mechanism for carry trade.

We reparameterize Equation 3 as an error-correction model. Table 4 shows our empirical findings. Column (1) reports the coefficient estimates with the risk variable (IMV) excluded. Column (2) displays bootstrapped standard errors. Carry traders are not sensitive to the forward premium in the long run. The coefficient of ID is instead, significant, supporting the idea that interest rate differentials act as the driving catalyst for the carry trade even in the face of macroeconomic shocks. In the short run, the forward premium FP is weakly significant with lag 1. Moreover, its sign is negative, consistent with the hypothesis that expectations of RMB depreciating might cause an unwinding of carry trade. The lagged-interest rate differential is negative showing opposite dynamics with respect to the long run, most likely due to mean-reverting behaviour of the rates. It takes 1 week for the interest-rate differential to have the most significant effect on copper carry trade deals. The speed of adjustment to long-run equilibrium, measured as the coefficient of the adjustment factor, implies that nearly

[14] See Pesaran and Shin (1998) and Pesaran et al. (2001)

[15] The F-stat is equal to 6.848, while the t-stat is -4.485.

3% of any disequilibrium from the long run is corrected within one period, one week in our data. The speed of adjustment is quite slow and consistent with the findings of Table 2.

The risk variable in Equation 3 is not significant as shown in Column (3). Insignificant IMV suggests that, due to the nature of the exchange rate USD/CNY, carry traders enter a position without considering risk. They are covered carry traders, or they focus exclusively on potential profit ignoring potential risks. Traders assign an extremely low probability to macro-financial shocks as effectively hedged by the PBOC. Figure 7 plots the 1-month USD/CNY FX option implied volatility, supporting our empirical findings. Despite a few spikes, especially since 2006, variation in implied volatility seems to be too negligible to be a key factor in our analysis.

Rather than speculating on the nature of the exchange rate, increases in copper value might also be driven by global growth explanation, raising the demand for commodities.[16] Column (4) includes the quarterly growth in industrial production to control for economic activity. The error-correction model still ensures convergence to a significant long run relationship. The forward premium and the interest rate differential are still significant in the short-run. The forward premium is not significant in the long-run, while the interest rate differential is weakly significant. Growth in industrial production is significant in the long run, while the risk variable is still insignificant. The error correction shows a low speed of adjustment even when controlling for risk and industrial production.

[INSERT TABLE 4 HERE]

[INSERT FIGURE 7 HERE]

As a second-tier decomposition of carry trade, we decompose ID and FP into four components as suggested in Figure 6, in order to identify the contribution of CHIBOR, SHIBOR the USD/CNY spot and forward rate. Our ARDL model is now as follows:

$$CV_t = \alpha_0 + \mathrm{X}\beta_i CV_{t-i} + \mathrm{X}\gamma_j SPOT_{t-j} + \mathrm{X}\eta_k FWD_{t-k} \tag{4}$$

[16] See Kilian and Hicks (2013).

$$+ \mathrm{X}\delta_l CHIBOR_{t-l} + \mathrm{X}\lambda_m LIBOR_{t-m} + \mathrm{X}\theta_n IMV_{t-n} + \varepsilon_t,.$$

Table 5 reports the coefficient estimates of Equation 4, when reparameterized as an error-correction model. Column (1) and (2) shows the base model with standard errors and bootstrapped standard errors, respectively. In the long run, both spot and forward rate are not significant, contradicting the hypothesis that FX rates affect carry trade. The offshore interest rate, as measured by LIBOR, is also not significant. Conversely, the onshore interest rate, as measured by CHIBOR, is significant. When we shift our attention to the short run, we observe that the lagged CHIBOR is significant, whereas LIBOR is not. The error-correction term is significant and negative. Changes in the forward rate affect the copper value, while the spot rate remains not significant even if in the near future. The adjustment speed is slightly faster than the previous model as shown by the coefficient of the adjustment factor, but still relatively slow and consistent with previous findings. The risk variable remains consistent with the findings of Table 4, i.e., not statistically significant. Column (4) includes the quarterly growth in industrial production to control for economic activity. The error-correction model still ensures convergence to a significant long run relationship. As in Column (1) and (3), FWD and CHIBOR are still significant in the near future, so is growth in industrial production. At the same time, SPOT and FWD remain insignificant in the long-run, neither is LIBOR. While, the risk variables are still not insignificant, CHIBOR and growth in the industrial production are statistically significant. The error correction shows a low speed of adjustment even when controlling for risk and industrial production.

We conclude that, in the long run, copper stock is driven by onshore-offshore interest differential, with the onshore interest rate driving up the copper value. Spot and forward exchange rates are not significant, consistent with FP not being a factor in the long run, due to the pegged nature of the exchange rate. In the near future, carry trade affects the copper value through both the forward rate and onshore-offshore interest differential through forward rate and CHIBOR in the near future. Moreover, when shifting our attention to the risk implied by such strategy, we show that carry traders are either fully hedged on FX risks, or they are unconcerned about FX risks.

[INSERT TABLE 5 HERE]

5 Conclusions

Standard carry trade is equivalent to borrowing low-interest-rate currencies in order to lend high-interest-rate currencies, without hedging the associated currency risk. High interest rates in the Chinese onshore market make the Renminbi a good target for the currency carry trade strategy, but this is problematic due to capital controls.[17] In such a scenario, a possible channel for cross-border capital flow is commodity trade financing. We show that covered carry trade returns drive copper value, with traders executing a profitable strategy with zero-risk involved, due to the pegged nature of the USD/CNY exchange rate. In particular, copper value is affected by interest rate differentials with onshore interest rate being a key factor. High average payoffs to the carry trade might also be due to the existence of a peso problem. Through demonstrating that FX risk does not affect the copper value, we rule out the possibility that peso problems can account for a major portion of the excess return associated with the carry trade, due to the natural hedging provided by capital control and the quasi-fixed exchange rate. We believe that our framework can be extended to investigate how, in a context of capital controls and quasi-fixed exchange rate, monetary policy and monetary policy shocks, expected and unexpected, might affect commodity prices and carry trade returns, consequently, and how copper traders react to monetary policy uncertainty.[18]

[17] Habib and Stracca (2012) show that currencies that are in less financially open economies provide good hedging against global risk.

[18] See Gospodinov and Jamali (2018).

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Table 1: Descriptive Statistics

This table reports the number of observations (N), average (Mean), standard deviation (S.D.), minimum (Min), first quartile (Q1), median (Q2), third quartile (Q3) and maximum (Max) for copper value (COPPER), covered carry trade return (CCR), 1-month onshore risk-free interest rate (CHIBOR), 1-month off shore risk-free interest rate (LIBOR), interest rate difference (ID), USD/CNY spot exchange rate (SPOT), USD/CNY 1-month forward exchange rate (FWD), forward premium (FP) and the USD/CNY 1-month option implied volatility (VOL). The sample period is from June 5, 2003 to February 23, 2017.

	N	Mean	S.D.	Min	Q1	Q2	Q3	Max
$COPPER$	717	658.423	470.536	49.747	238.844	595.758	1007.491	1859.565
CCR	717	0.020	0.024	-0.029	0.008	0.020	0.036	0.125
$CHIBOR$	717	0.034	0.014	0.010	0.025	0.032	0.041	0.140
$LIBOR$	717	0.015	0.018	0.001	0.002	0.004	0.025	0.058
ID	717	0.019	0.025	-0.031	0.006	0.021	0.037	0.138
$SPOT$	717	7.024	0.778	6.051	6.347	6.827	7.869	8.278
FWD	717	7.017	0.766	6.096	6.341	6.820	7.850	8.278
FP	717	-0.007	0.035	-0.088	-0.015	0.008	0.029	0.143
VOL	717	2.412	1.425	0.250	1.450	1.970	3.130	8.250

Table 2: Cointegration Analysis

Panel A reports the cointegration equation for copper value (COPPER) and covered carry trade return (CCR), with standard errors. Panel B reports the vector-error correction model estimates. Column (1) and (2) reports the parameter estimates with classical and bootstrapped standard errors, respectively. Panel C reports the Toda-Yamamoto causality test. The sample period is from June 5, 2003 to February 23, 2017.

Panel A: Cointegration equation	
$COPPER$	1.000
CCR	-1.671***
	(0.321)

Panel B: VECM estimates			
	(1)	(2)	
	0.207***	0.207***	
	(0.037)	(0.000)	
	0.155***	0.155*	
	(0.037)	(0.010)	
$\Delta COPPER_{t-1}$	0.084**	0.084**	
	(0.039)	(0.001)	
$\Delta COPPER_{t-2}$	0.156***	0.156*	
	(0.037)	(0.006)	
$\Delta COPPER_{t-3}$	-0.071**	-0.071**	
	(0.027)	(0.002)	
$\Delta COPPER_{t-4}$	0.006	0.006	
	(0.028)	(0.001)	
ΔCCR_{t-1}	0.020	0.020	
	(0.026)	(0.003)	
ΔCCR_{t-2}	0.037	0.037*	
	(0.027)	(0.001)	
ΔCCR_{t-3}			
ΔCCR_{t-4}	(2.075)	(0.054)	
	712	712	
Error correction	0.178	0.178	
term	152.13	153.13	-0.023*
	(0.005)		(0.001)
Intercept	0.773	0.773*	

***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Table 3: Multivariate Analysis

The table reports estimation results based on a multivariate analysis. Column (1) is an autoregressive model of order 3. Column (2) reports bootstrapped standard errors. Column (3) adds the USD/CNY spot exchange rate (SPOT). Column (4) reports the bootstrapped standard errors. The sample period is from June 5, 2003 to February 23, 2017.

	(1)	(2)	(3)	(4)
ΔCV_{t-1}	0.2057***	0.2057***	0.2084***	0.2084***
	(0.038)	(0.040)	(0.038)	(0.040)
ΔCV_{t-2}	0.1453***	0.1453***	0.1436***	0.1436***
	(0.038)	(0.051)	(0.038)	(0.053)
ΔCV_{t-3}	0.0662*	0.0662	0.0674*	0.0674
	(0.038)	(0.055)	(0.039)	(0.049)
ΔCV_{t-4}	0.1373***	0.1373***	0.1352***	0.1352***
	(0.038)	(0.047)	(0.038)	(0.048)
$\Delta SPOT_{t-1}$			-0.0109	-0.0109
			(0.011)	(0.010)
$\Delta SPOT_{t-2}$			0.0100	0.0100
			(0.011)	(0.012)
$\Delta SPOT_{t-3}$			-0.0060	-0.0060
			(0.011)	(0.016)
$\Delta SPOT_{t-4}$			0.0132	0.0132
			(0.011)	(0.014)
Intercept	0.9778	0.9778	1.098	1.098
	(2.101)	(2.260)	(2.135)	(2.345)
Observations	712	712	712	712
F-stat	119.18	67.16	122.98	69.68
Adjusted R^2	0.1385	0.1385	0.1376	0.1376

***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Table 4: Tier 1 ARDL model

This table reports the ARDL estimates for the Tier 1-model. The coefficient estimates for the base model are shown in Column(1) with standard errors shown in parentheses. Column (2) reports the bootstrapped standard errors. Column (3) reports the coefficient estimates when implied volatility is added. Column (4) reports the coefficient estimates when controlling for quarterly growth in industrial production (lnIP). The sample period is from June 5, 2003 to February 23, 2017.

			-3.6712	-2.6775
			(5.200)	(5.219)
				0.0111*
				(0.006)
	0.0029	0.0029	0.0029	0.0020
	(0.003)	(0.003)	(0.003)	(0.002)
	1.2243***	1.2243***	1.2205***	0.6896*
	(0.350)	(0.375)	(0.344)	(0.366)
			-138.77	-81.262
			(196.066)	(158.847)
				0.3365**
				(0.159)

	(1)	(2)	(3)	(4)
ΔCV_{t-1}	0.2306***	0.2306***	0.2310***	0.2336***
	(0.037)	(0.044)	(0.037)	(0.037)
ΔCV_{t-2}	0.1795***	0.1795***	0.1789***	0.1844***
	(0.037)	(0.053)	(0.037)	(0.037)
ΔCV_{t-3}	0.1150***	0.1150**	0.1146***	0.1222***
	(0.038)	(0.051)	(0.038)	(0.038)
ΔFP_t	0.0001	0.0001	0.0001	0.0001
	(0.000)	(0.000)	(0.000)	(0.000)
ΔFP_{t-1}	-0.0003**	-0.0003**	-0.0003**	-0.0003**

	(1)	(2)	(3)	(4)
	(0.000)	(0.000)	(0.000)	(0.000)
ΔID_t	0.0124	0.0124	0.0106	0.0068
	(0.027)	(0.035)	(0.027)	(0.027)
ΔID_{t-1}	-0.0940***	-0.0940**	-0.0937***	-0.0907***
	(0.027)	(0.039)	(0.027)	(0.027)
ΔIMV_t				
$\Delta \ln IP_t$				
FP_{t-1}				
ID_{t-1}				
IMV_{t-1}				
$\ln IP_{t-1}$				
Intercept	12.7014***	12.7014***	13.0628***	-75.9084
	(3.976)	(3.127)	(4.010)	(48.715)
Adjustment factor	-0.0261***	-0.0261***	-0.0265***	-0.0329***
	(0.006)	(0.007)	(0.006)	(0.007)
Observations	713	713	713	713
Adjusted R^2	0.1584	0.1584	0.1578	0.1606

Note: ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Table 5: Tier 2 ARDL model

This table reports the ARDL estimates for the Tier 2-model. The coefficient estimates for the base model are shown in Column(1) with standard errors shown in parentheses. Column (2) reports the bootstrapped standard errors. Column (3) reports the coefficient estimates when implied volatility is added. Column (4) reports the coefficient estimates when controlling for quarterly growth in industrial production. The sample period is from June 5, 2003 to February 23, 2017.

		-2.2450	-2.0829
		(5.389)	(5.382)
			0.0264*
			(0.015)
-0.2781	-0.2781	-0.2753	-0.1884
(0.219)	(0.263)	(0.219)	(0.204)
0.2567	0.2567	0.2547	0.2260
(0.221)	(0.266)	(0.221)	(0.202)
1.0312*	1.0312	1.0447*	0.9994*
(0.624)	(0.696)	(0.625)	(0.571)
-0.5888	-0.5888	-0.6068	-0.8007
(0.531)	(0.382)	(0.533)	(0.506)
		-72.9730	-62.1267
		(175.573)	(160.822)
			0.7871*
			(0.435)

	(1)	(2)	(3)	(4)
ΔCV_{t-1}	0.2301***	0.2301***	0.2301***	0.2306***
	(0.037)	(0.043)	(0.037)	(0.037)
ΔCV_{t-2}	0.1842***	0.1842***	0.1838***	0.1858***
	(0.037)	(0.053)	(0.037)	(0.037)
ΔCV_{t-3}	0.1163***	0.1163**	0.1163***	0.1209***
	(0.038)	(0.051)	(0.038)	(0.038)
$\Delta SPOT_t$	-0.0085	-0.0085	-0.0085	-0.0063

	(0.007)	(0.008)	(0.007)	(0.007)
ΔFWD_t	0.0080	0.0080	0.0090	0.0063
	(0.010)	(0.010)	(0.010)	(0.011)
ΔFWD_{t-1}	-0.0221**	-0.0221**	-0.0220**	-0.0244***
	(0.009)	(0.011)	(0.009)	(0.009)
$\Delta CHIBOR_t$	0.0176	0.0176	0.0166	0.0163
	(0.028)	(0.037)	(0.028)	(0.028)
$\Delta CHIBOR_{t-1}$	-0.0929***	-0.0929**	-0.0928***	-0.0945***
	(0.028)	(0.041)	(0.028)	(0.028)
$\Delta LIBOR_t$	-0.0181	-0.0181	-0.0187	-0.0268
	(0.016)	(0.012)	(0.016)	(0.017)
ΔIMV_t				
$\Delta \ln LIP_t$				
$SPOT_{t-1}$				
FWD_{t-1}				
$CHIBOR_{t-1}$				
$LIBOR_{t-1}$				
IMV_{t-1}				
$\ln IP_{t-1}$				
Intercept	59.4377	59.4377**	57.8226	-298.4702
	(36.962)	(28.832)	(37.186)	(203.593)
Adjustment factor	-0.0307***	-0.0307***	-0.0308***	-0.0335***
	(0.007)	(0.008)	(0.007)	(0.007)
Observations	713	713	713	713
Adjusted R^2	0.1593	0.1593	0.1583	0.1609

Note: ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

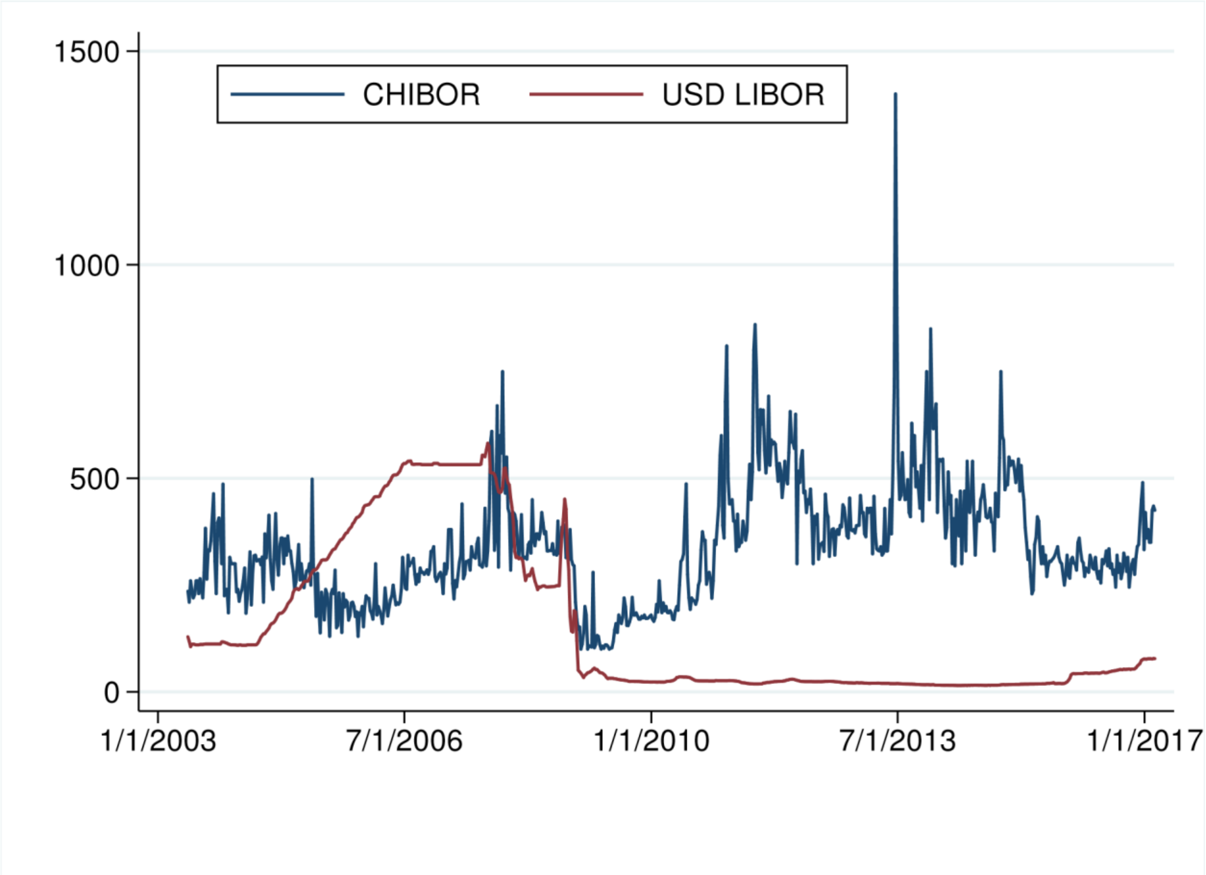

Figure 1: Onshore interest rate (CHIBOR) and offshore interest rate (1-month USD LIBOR), basis points, 2003-2017

Figure 2: Copper stock shifts from the rest of the world to Shanghai, 2009-2015

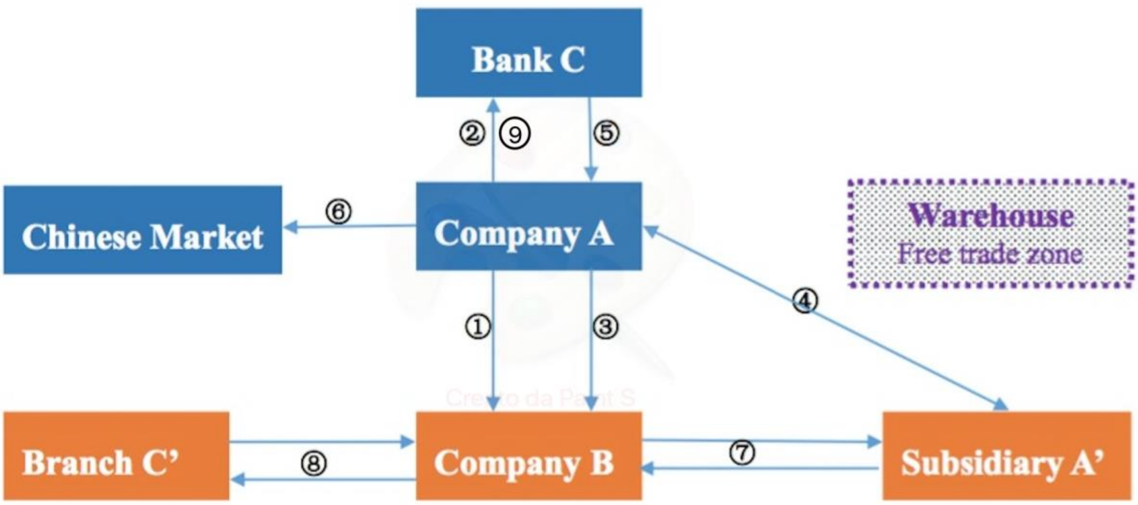

Figure 3: Carry trade returns via copper trade

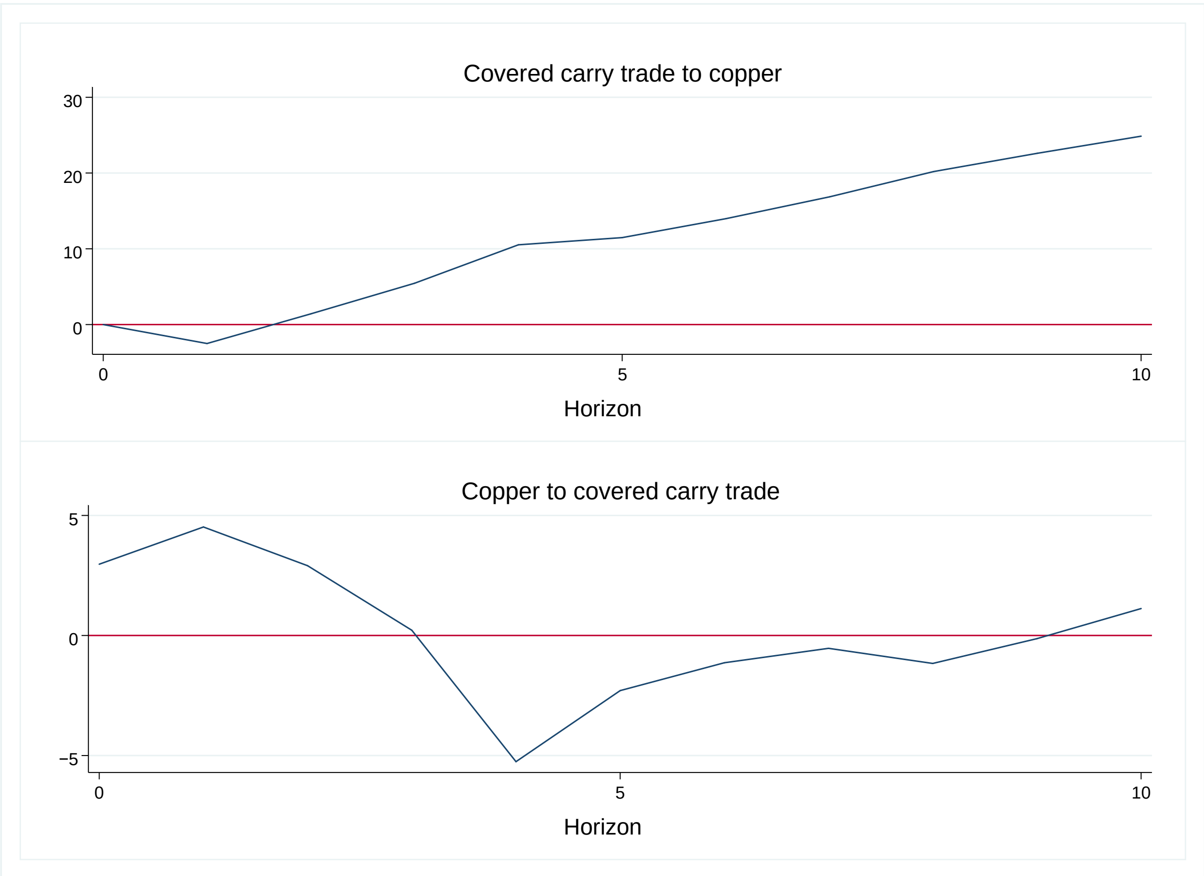

Figure 4: Orthogonal impulse response function from covered carry trade return to copper (upper figure) and from copper to covered carry trade return (lower figure)

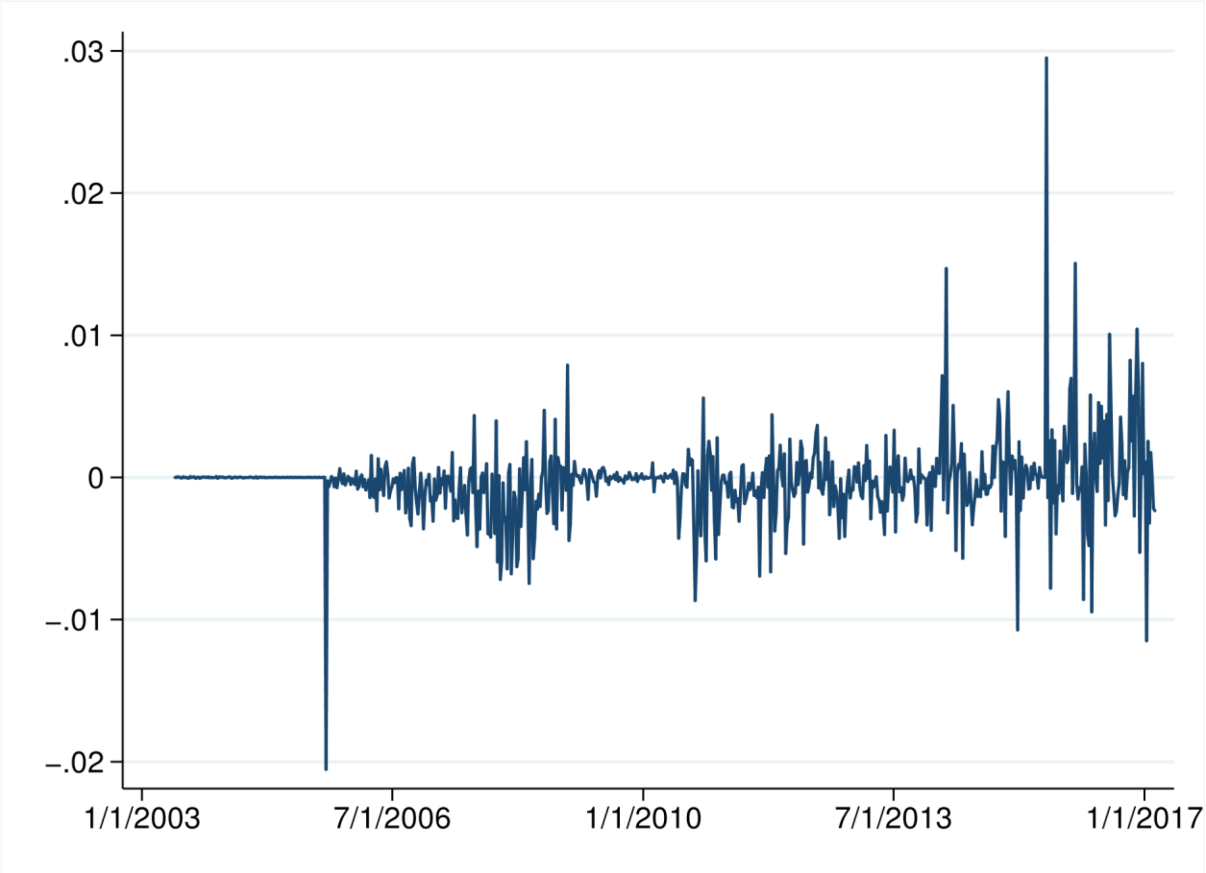

Figure 5: Changes in USD/CNY spot rate, 2003-2017

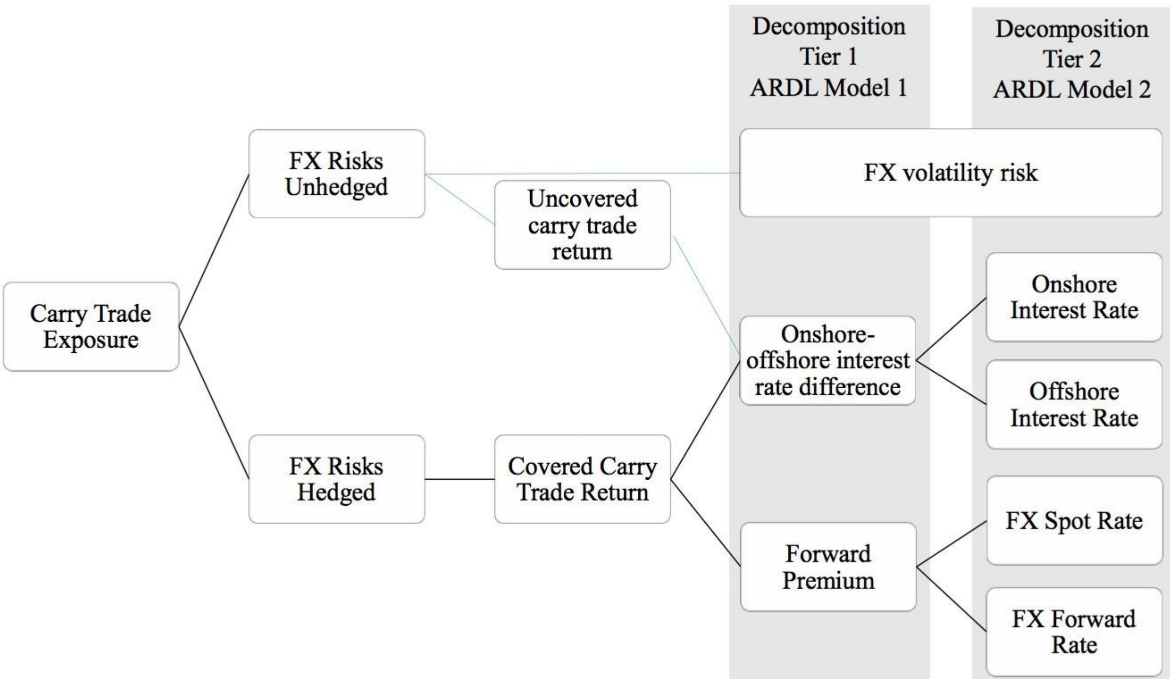

Figure 6: Decomposing carry trade exposure

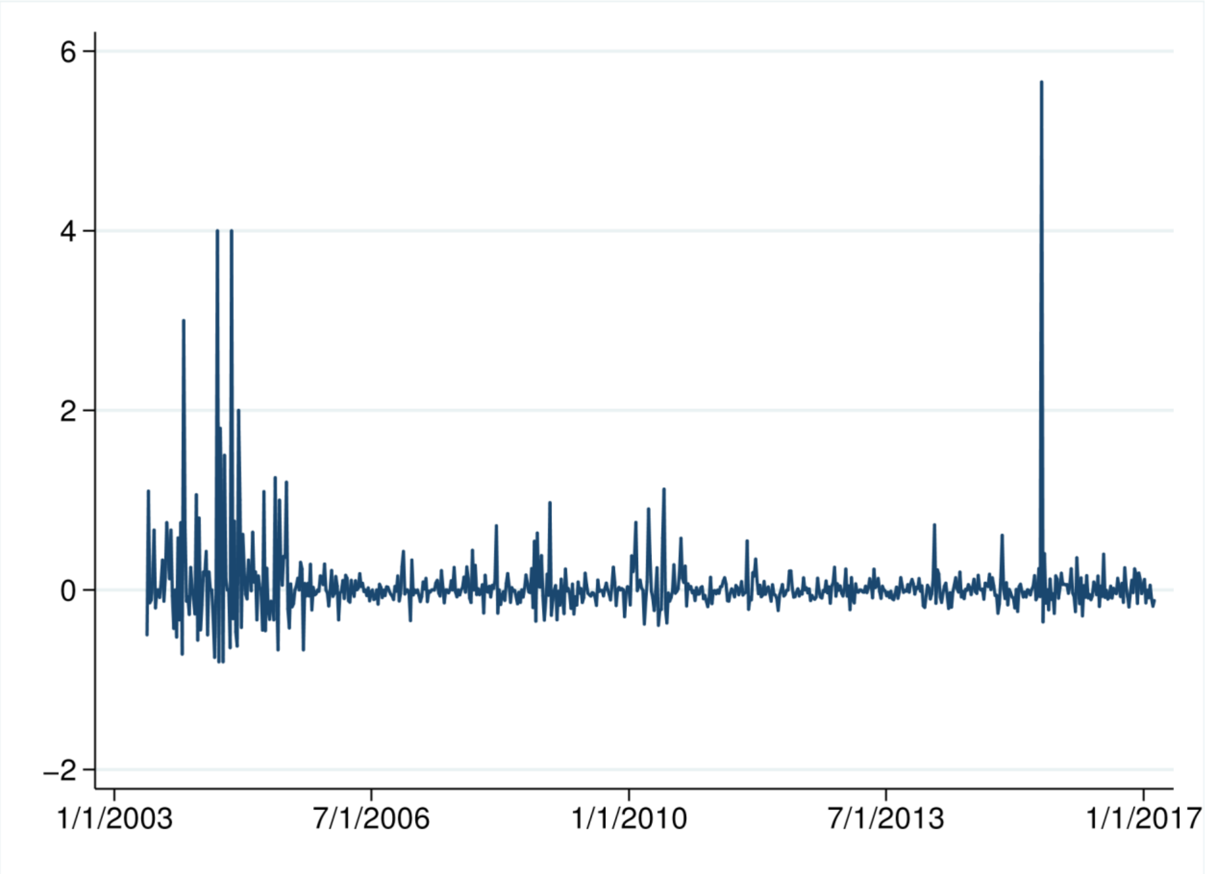

Figure 7: Changes in 1-month ATM USD/CNY FX option implied volatility, 2003-2017