China's capital controls and the volatility of the renminbi covered interest deviation

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Abstract: This paper examines how China's capital controls affect the volatility of the renminbi (RMB) covered interest deviation (CID). We find that capital controls amplify the volatility of RMB CID and the amplification effect becomes more prominent in more flexible RMB exchange regimes. To understand the mechanism of the volatility amplification effect, we decompose the RMB CID into two components: interest rate differential (IRD, the money market component) and forward premium (FP, the foreign exchange market component), and find that, while capital controls normally amplify the volatility of both, they mitigate the volatility of the IRD during the U.S. Fed's quantitative ease (QE) era. Moreover, using an error correction model that allows to study short-run and long-run volatility simultaneously, we show that, while capital controls increase both the short- and long-run volatility of the IRD and the CID overall, they do not affect FP volatility.

Keywords: Capital controls, Covered interest deviation (CID), Amplification effect, CID volatility, Interest rate differential, Forward premium
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1. Introduction

The remarkable rise in cross-border capital flows in emerging markets (EMs) and the subsequent boom-bust cycle of capital flows in past decades have spurred a surging literature that supports capital controls as a viable tool to buffer financial shocks and stabilize financial structure (Ostry et al. 2010; 2011) [1]. Indeed, the International Monetary Fund (IMF) endorses capital controls as part of a macro-prudential policy toolkit (IMF, 2011, 2012) and recommends a set of guidelines on the appropriate use of capital account management (IMF, 2013).

Although capital controls help insulate external shocks and enhance financial stability, they may play roles in reducing financial market efficiency and creating financial volatility. For example, capital controls could restrict an exchange and payment system, thus change market perceptions about the risks of domestic assets, consequently, they can create exchange rate volatility in the short run (Frenkel et al., 2002). In addition, capital controls could narrow the cross-border arbitrage channel and cause greater volatility in the onshore–offshore exchange rate differential (Funke et al., 2015). Capital controls are also found to limit risk sharing channel, inducing exchange rate volatility (Calderon and Kubota, 2018).

While those studies focus on how capital controls amplify the volatility of exchange rate, this paper explores a new research topic by examining how capital controls affect the volatility of covered interest deviation (CID), which may have important implication on financial stability. The literature has extensively scrutinized how capital controls affect CID? The common finding is that capital controls act as transaction taxes that effectively raise cross-border arbitrage costs and drive up the level of CID (Dooley and Isard, 1980; Ito, 1983). However, it is unclear how capital controls affect the volatility of CID (the second moment of CID)? In this paper, we attempt to answer this question by using Chinese economy as a laboratory to study the association between China's capital controls and the volatility of the renminbi (RMB) CID[2].

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[1] Also see, for example, Benigno et al. (2016), Farhi and Werning (2014), Han and Wei (2018), Korinek and Sandri (2016), and Zeev (2017).

[2] There are two reasons that motivate us to use Chinese economy as the study model. First, China has capital controls and they are still binding and effective (Cheung and Herrala, 2014; Ma and McCauley, 2008). Second, CID volatility is a financial variable that responses policy changes quickly. Thus, high frequency data is necessary to capture this short-term dynamic. However, most capital controls data are usually in annual frequency. See for example, Chinn and Ito (2008) and Fernandez et al. (2016). We obtain high frequency (monthly) data [Chen and Qian's (2016) China's capital control index] for China's capital controls that allows use study shot-term respond of CID volatility to capital controls.

In international finance, CID measures the interest rate difference between the onshore money market interest rate and the synthetic offshore interest rate obtained by converting a foreign currency into domestic currency covered by forward or swap contract hedge. Thus, CID represents the return rate sought by arbitrageurs and speculative cross-border capital flows (Levich, 2017). Volatile investment return rate (e.g. the volatile CID) induces volatile cross-border capital flows and ensues possible financial instability. As an illustration, we plot China's illicit cross-border capital flows[3], the renminbi (RMB) CID, and capital controls in Figure 1. The wide swings of China's illicit cross-border capital flows that destabilize China's financial system appear to be closely associated with the high volatility of the RMB CID. Interestingly, despite the important implication for financial stability, the literature lacks analysis of how capital controls affect the volatility of CID.

This paper uses monthly data of Chinese economy to study how capital controls affect the volatility of the RMB CID. Following the postulation of trilemma paradigm that countries face a trade-off among the objectives of exchange rate stability, free capital mobility, and independent monetary policy (Mundell, 1963), we study how the liberalization of RMB exchange rate regime and the U.S. monetary policy affect the role of China's capital controls on RMB CID volatility. In addition, to identify the plausible channel through which China's capital controls affect the volatility of the RMB CID, we decompose the CID into its two components, the interest rate differential (IRD), which represents the monetary market channel, and the forward premium (FP), which captures the foreign exchange market channel and analyze how capital controls affect the volatility of IRD and FP individually. Finally, considering that capital controls are highly durable, and the effect of capital controls is usually long lasting (Eichengreen and Rose, 2014), we examine how capital controls affect the long- and short-run CID volatility.

Our findings suggest that tight controls on cross-border capital flows are associated with high volatility of the RMB CID. Specifically, a one standard deviation tightening of China's capital controls induces about one standard deviation higher volatility in the RMB CID. The effect of capital controls to amplify the volatility of the RMB CID may stem from capital controls' role to limit the mobility of cross-border arbitraging capital flows, thus shallowing the offshore market liquidity and, consequently, leading to high offshore financial market volatility.

[3] These are the cross-border capital flows that circumvent capital controls (also known as capital flight). We compile the data of illicit capital flows by using the World Bank's residual method. The illicit capital flows are labeled as capital flight in Figure 1.

The volatility amplification effect is stronger when the RMB is in a more flexible exchange regime, for example, the one (dubbed as "controlled floating") after August 2015, when the demand and supply in the foreign exchange market has greater influences on the RMB exchange rate. Quantitative easing (QE) monetary policy from the United States (the center country) creates a spillover effect—although capital controls amplified the RMB CID volatility before QE, they mitigated it during QE periods. The QE spillover may reflect China's independent monetary policy to quell external shocks in the presence of capital controls and relatively flexible exchange rate regime. This finding is consistent with the postulation of Mundell-Fleming "trilemma" paradigm.

Considering how capital controls affect the volatility of two CID components, IRD and FP, our results suggest that capital controls amplify the volatility of the IRD, except during the Fed's QE era, when China appeared to exert more monetary policy autonomy (Chang et al., 2015), capital controls mitigated IRD volatility. Meanwhile, capital controls increase FP volatility in more flexible exchange rate regimes after August 2015. Thus, the overall effect of capital controls on RMB CID volatility in normal periods is the sum of the amplification of both the IRD and FP. However, during the overlapping periods between the QE era[4] and the periods when China had more flexible exchange regimes, there was a tradeoff effect between muffling IRD volatility and amplifying FP volatility. Since the marginal effect of capital controls on amplifying FP volatility (foreign exchange market channel) dominated the mitigating effect on the IRD volatility (monetary market channel), the overall effect was for China's capital controls to increase the volatility of the RMB CID.

Regarding the durable and lasting effect of capital controls suggested by Eichengreen and Rose (2014), we examine how capital controls affect the long- and short-run CID volatility simultaneously in an error correction model (ECM). The results indicate that capital controls are positively associated with long-run CID volatility and that the tighten-up of capital controls increases short-run CID volatility. Thus, China's capital controls are found to increase both the long-run and short-run volatility of the CID. However, when examining the volatility of IRD and

[4] The Fed started QE by purchasing mortgage-based securities and treasury securities immediately after the 2008 financial crisis. It subsequently implemented QE2 and QE3 until October 29, 2014, when it halted the purchases after accumulating $4.5 trillion in assets. However, the Fed's decision to end its bond-buying program did not mark the end of its efforts to stimulate the economy (Wolfers, 2014); the Fed expects interest rates to remain low for "a considerable time" (Federal Reserve Bank, 2014). For these reasons, we include the sample years 2015 and 2016 in the QE era.

FP, we find no evidence that capital controls affect the long-run FP volatility in the offshore foreign exchange market. In the short run, increases in the strictness of capital controls substantially increase the volatility of the FP under the more flexible exchange rate regime following the August 2015 exchange rate reform.

This paper contributes to the literature in three respects. First, most studies focus on how capital controls can insulate emerging market economies from external shocks [e.g. boom-bust cycle of capital flows (Ostry et al. 2012), credit supply shocks (Zeev, 2017), and monetary policy shocks emanated from advanced economies (Han and Wei, 2018)] and maintain financial stability. By contrast, we study the rarely explored role of capital controls in amplifying the volatility of the CID and the ensuing financial instability. Thus, our findings may have macroeconomic policy implication - when implementing capital flow restrictions for the macro-prudential purpose, policymakers need to be aware of the side-effect caused by the externality of capital controls as they might amplify CID volatility, reduce financial market efficiency, and create financial instability.

Second, while some studies[5] identify the role of capital controls in increasing foreign exchange rate volatility, they pay little attention to capital controls' effect on the volatility of IRD, which may reflect a country's capacity of monetary policy autonomy in maintaining financial stability[6]. Our study examines both the volatility of IRD and FP, two integrated components of CID, to identify plausible channels through which capital controls increase CID volatility. The overall effect of capital controls turns out to be complex. It is the combined amplification effect on both IRD and FP volatility in normal time; however, during QE era, it is the trade-off between capital controls' amplification effect on FP volatility through the foreign exchange market channel and their mitigating effect on IRD volatility via the channel of monetary market.

Third, studies that examine how exchange rate volatility is associated to capital controls usually do not differentiate whether the association is a short-tern reaction or a long-term convergence. For example, Edwards and Rigobon (2009) find that tightening of capital controls that segmented the Chilean foreign exchange market from external shocks increased the

[5] See for example, Edwards and Rigobon (2009), Frenkel et al. (2002) and Funke et al. (2015).

[6] Magud et al (2108) summarize the rational of capital controls into "four fears", namely, fear of appreciation, fear of "hot money", fear of large inflows, and fear of loss of monetary autonomy. Their findings indicate that capital controls affect an emerging economy through foreign exchange market, cross-border capital flows, and money market.

unconditional volatility of the exchange rate and made it less sensitive to external shocks. Funke et al. (2015) find loose capital controls on RMB outflows reduced the volatility of the onshore-offshore RMB exchange rate differential. Both papers use GARCH model to identify the short-term dynamic of exchange rate volatility and capital controls. By contrast, we reveal some extra dynamics by analyzing how capital controls affect the long-run and short-run volatility of the CID simultaneously in an ECM. Understanding how the volatility of CID is associated with capital controls in short- and long-term separately may help countries set macroprudential policies that focus on either short-term or long-term objective more effectively.

The remainder of our paper is organized as follows. Section 2 provides a brief literature review. Section 3 describes the data and specifies the methodology. We analyze how capital controls affect the volatility of CID, IRD, and FP in Section 4. Section 5 examines capital controls and the long-run volatility of CID. Section 6 provides additional analyses and robustness checks. Section 7 concludes.

2. A review of the related literature

Engagement in financial openness enables EMEs to be integrated into the global financial system significantly. However, financial openness and rising capital mobility seem to be perceived as a factor associated with the financial instability of EMEs. For example, large amounts of capital inflows to EMEs in the early 1990s fueled a credit boom and resulted in substantial appreciation of the real exchange rates of those economies, causing devastating financial crises in East Asia and Russia in the late 1990s and in South America in the early 2000s. The adverse effect of financial openness on financial stability altered the long-held view of capital controls as a distortion to economic growth. The IMF reversed its original view against capital controls, suggesting that they were a viable tool in the macro-prudential toolkit to safeguard financial stability (IMF, 2011, 2013).

Tobin (1974) first proposed the use of capital controls to fend off external shocks and maintain economic stability. He argued that a Tobin tax on foreign exchange transactions reduces speculative capital flows (a.k.a hot money). There has been renewed research interest in support of capital controls as a viable policy tool to stabilize financial structure since the 2008 global financial crisis. For example, Ostry et al. (2010, 2011) provided evidence that EMEs with capital inflow controls prior to the 2008 global financial crisis suffered less than other EMEs. Ostry et al. (2012) further examined whether macro-prudential policies and capital controls enhanced financial stability when facing risk induced by large capital inflows. Their findings suggest that macro-prudential and capital control policies in place during the boom enhanced financial resilience amid the bust. In a recent study, Zeev (2017) empirically confirmed the relevance of capital controls as an effective policy instrument by studying the shock-absorbing capacity of capital controls in 33 EMEs. He found that the output of economies with stricter capital inflow controls reacted less to global credit supply shock. Perceiving that capital controls may buffer the spillover effect of a monetary policy shock, Han and Wei (2018) studied how capital controls could help to buffer and insulate EMEs from monetary policy shocks emanated from advanced economies. The authors showed on the one hand that a flexible exchange rate regime offered EMEs some monetary policy independence when the Fed tightened its monetary policy but failed to do so when the Fed lowered the US interest rate. Capital controls, on the other hand, helped to insulate EMEs from shocks when the Fed lowered its interest rate.

Recently, some related theories have been developed to reveal plausible mechanisms through which capital controls promote financial stability. Farhi and Werning (2014) used a standard new Keynesian model with nominal rigidities and found that optimal capital controls help to smooth capital flows. In their model, capital controls act as temporary subsidies on inflows and taxes on outflows, and thus, mitigate the required monetary policy responses during sudden stops to depreciate the exchange rate and increase the nominal interest rate. Similarly, Benigno et al. (2016) suggested that, within the framework of cost-effective macro-prudential policies to maintain financial stability, a mixed use of capital controls in tranquil times (as a way to limit the occurrence of crises) with policies that limit exchange rate depreciation in crisis times resulted in an increase in borrowing, but fewer and less severe financial crises. Meanwhile, Korinek and Sandri (2016), explicitly separated the role of macro-prudential regulations and capital controls, and found that while macro-prudential regulation reduces indebtedness, capital controls induce more precautionary behavior for the economy as a whole. Their model demonstrated that prudential capital controls can induce agents to internalize their externalities and to increase macro stability and welfare.

Despite their stabilizing role in the financial system, capital controls have some downside effect on financial stability, particularly in terms of reducing financial market efficiency (e.g., limiting capital mobility and allocation distortion) and creating exchange rate volatility. Montecino (2018) argued that, in theory, capital controls limit capital stock to allocate across sectors. Employing an empirical model with data from both developed and developing countries, he found that capital controls slow down the speed of exchange rate adjustment toward the long-run equilibrium and thus, increase the misalignments of the real exchange rate. Calderon and Kubota's (2018) study on openness and real exchange volatility concluded that restrictions on financial openness amplify the real exchange rate volatility in countries with a higher share of foreign debt liabilities vis-à-vis foreign equities. The rationale for this finding is that a greater share of equity in a country's external investment position can improve risk sharing and thus, the country's resilience to external shocks (Rogoff, 1999).

Our research is closely related to two important studies that investigate the role of capital controls on exchange rate volatility. Edwards and Rigobon (2009) evaluated how Chilean capital controls on inflows reduced vulnerability to external shocks. Using a generalized autoregressive conditional heteroscedasticity (GARCH) model and explicitly considering the interaction between capital controls and the managed exchange rate regime with targeted bands, the authors found that tightening of capital controls that segmented the Chilean foreign exchange market from external shocks increased the unconditional volatility of the exchange rate and made it less sensitive to external shocks. Our base findings are in line with these results. However, augment from their approach, we take a step further by explicitly separating capital controls' influence on the long-run and short-run aspects of exchange rate volatility. In addition to investigating capital controls' effect on exchange rate market volatility, we examine their effect from monetary market channel, and find that capital controls help to mitigate the volatility of the differential between the domestic and international interest rates after the 2008 global financial crisis. This finding is consistent with the identified role of capital controls in insulating monetary shocks from center country and maintaining monetary policy independence (Rey, 2015; Han and Wei, 2018).

Our study is related is the work Funke et al. (2015), which investigates the level and volatility of onshore–offshore RMB exchange rate differentials in an augmented GARCH model. These authors found that global risk aversion led to an increase in the volatility of the RMB exchange rate differential, whereas loose controls on RMB outflows reduced the differential's volatility. The rationale is that easy capital mobility reduced the onshore–offshore liquidity gap, thereby smoothing the price gap for the same unit of RMB. While consistent with these authors' findings, our findings refer to a broader issue—the volatility of CID, which includes both the volatility of onshore–offshore exchange rate differential and the interest rate differential (IRD). On the one hand, capital controls act as a shock absorber to mitigate external monetary policy shocks; on the other hand, capital controls set up barriers to limit the mobility of capital flows, thereby lowering the efficiency of financial markets resulting in higher volatility of the RMB CID.

3. Data and methodology

3.1 Data

We first describe the data used for the empirical investigation and some facts about Chinese economy based on patterns observed in the data. Depending on availability, we used monthly data from January 1999 to December 2016. We checked all the time-series data for unit roots; then, we took the first difference to convert it into I(0) if a variable is non-stationary.

The RMB CID is the deviation from the covered interest rate parity, which can be interpreted as the onshore–offshore money market return after taking account of the rate of RMB appreciation. A positive CID value suggests a higher onshore money market interest rate than offshore one, which may attract capital inflows seeking higher returns. Mathematically, $CID = (r - r^*)/(1 + r^*) - (F - S)/S$, where $(r - r^*)/(1 + r^*)$ is the IRD and $(F - S)/S$ is the expected rate of appreciation or FP. The variables r and r^* are the Chibor and US dollar (USD) Libor rate, respectively; S is the spot rate quoted as units of RMB per USD; and F is the RMB non-deliverable forward (NDF) rate. Following the literature, we used 3-month Chibor, Libor, and NDF rates. The volatility of RMB CID is an unconditional variance calculated as the month variance from daily CID data. Daily CID is compiled from daily Chibor, U.S. dollar Libor, NDF rate, and spot exchange rate. We obtained the data for interest rates and exchange rates from Bloomberg and Datastream.

The unconditional variances for IRD and FP are calculated using the same approach as CID's. In statistics, the variance of CID is the sum of IRD and FP variance, adjusted for the covariance of IRD and FP; that is, *var_CID = var_IRD + var_FP - 2*cov(IRD, FP)*. However, the *cov(IRD, FP)* during our sample periods is -0.0003, which is rather trivial compared to the average variance of IRD and FP (0.032 and 0.051, respectively). For simplification, we dropped the covariance from the equation and assumed that the variance of CID equals the sum of the variances of IRD and FP.

Regarding the measurement for China's capital controls, we use Chen and Qian's (2016) index data, which numerically measure the strictness of China's capital controls. These monthly indexes, namely, *KC, KCi,* and *KCo,* measure overall capital account restrictions, capital inflow, and outflow restrictions, respectively. A larger value for each index indicates a more restrictive level of capital control. Figure 1 plots China's overall control level (*KC*) in green[7].

During the course of our analysis, we attempt to use other indexes, including Chinn and Ito's (2008) financial openness index and Fernandez et al.'s (2016) capital control index; however, both measures (in yearly frequency) for China's capital controls appear to be too coarse to capture the effect of the gradual liberalization of China's controls on its capital accounts[8].

There are three advantages to using Chen and Qian's (2016) index. First, the monthly series allow us to study the RMB CID with high-frequency data. Second, the Chen and Qian (2016) index focuses on China and accounts China's gradual liberalization on all categories of capital accounts, including equities, bond securities, money market instruments, commercial credits, financial credits, and FDI, thus providing a better measurement of China's capital controls than other capital control (financial openness) indexes. Third, China has often implemented controls on capital inflows and outflows at different paces and intensities according to different domestic and global situations. The Chen and Qian (2016) index can capture these variations in pace and intensity for both inflow and outflow controls.

To capture China's RMB exchange rate regime liberalization during our sample periods, we use time dummy variables. China experienced two major reforms of the RMB exchange rate regime after 1999. The first occurred on July 21, 2005, when China announced a 2.1% appreciation of the RMB against the USD and moved to a managed float, with reference to an undisclosed basket of currencies that replaced the original peg to the USD. The RMB value was said to become more flexible and based more on "market supply and demand." The second major

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[7] Table 1 provides summary statistics for all variables.

[8] For example, the Chinn–Ito index indicates that China's capital controls have not changed from -1.20 since 1993. The index of Fernandez et al. (2016) shows that China had the same level capital controls until 2013 when the control level lowered from 1 to 0.9.

reform occurred on August 11, 2015, when the People's Bank of China revamped the central parity formation mechanism to create a "controlled floating" and increase RMB exchange rate flexibility. The new regime sets the RMB central parity against the USD by referencing the closing rate of the previous trading day; thus, the RMB value depends on market demand and supply as well as the valuations of other currencies. The RMB exchange rate experienced an unexpected large depreciation immediately after the announcement of the new policy, generating substantial volatility in the foreign exchange market. This depreciation and the volatile market situation extended to the end of 2016 (Cheung et al. 2018). Based on this situation, we use time dummy variables to capture these two periods of exchange rate regime liberalization: *Reform 2005* = 1 (t >=July 2005; otherwise, 0) and *Reform 2015* = 1 (t >= August 2015: otherwise, 0).

We define the Fed's QE variable (*QE*) in a similar manner. We set *QE* = 1 after February 2009 when the American Recovery and Reinvestment Act of 2009 was signed into law; otherwise, we set it to 0. Observing that the 2008 global financial crisis shocked the RMB CID substantially (Figure 1), we created a time dummy to capture this shock: let *GFC* = 1 between December 2007 and June 2009 (the NBER definition of 2008 financial crisis); otherwise, we set it to 0. The definition and data sources of other relevant variables are described in Appendix Table A1.

3.2 Empirical methodology

In this subsection we set up regression models to examine how capital controls affect the volatility of RMB CID. We construct the baseline regression as follows:

$$VCID_t = c + \sum_{p=1} \alpha_p \; VCID_{t-p} + \beta \; KC_t + X_t' \; \varphi + \varepsilon_t \qquad (1)$$

where $VCID_t$ is the unconditional variance of the RMB CID. c is a constant. $VCID_{t-p}$is lagged dependent variables. We estimate equations (1) using the autoregressive distributed lags model (ARDL), which allows to include lagged dependent variables as regressors. Two reasons that motivate us to use the ARDL mode. First, volatility data are time persistent and the data variation can be explained by its history (Engle, 2001). The ARDL model addresses these issues. Second, the ARDL model that includes lagged dependent variables addresses serial correlations in error terms that cause estimation bias in time series regressions. The lag structure of the lagged dependent variable $VCID_{t-p}$ is determined by the Bayesian information criterion and by the properties of the estimated residuals.

KC measures the strictness of China's capital controls. We include aggregate *KC* (overall level of capital controls), *KCi* (controls on capital inflows), and *KCo* (controls on capital outflows) in the regression. Using *KCi* and *KCo* has two purposes. First, the literature indicates that capital controls on inflows and outflows have different effectiveness on different situations. On one hand, Krugman (1998) advocated for Malaysian-type outflow controls, arguing that imposing capital outflow controls benefits a country when it is already facing a crisis. Those controls allow the country to lower interest rates and deploy pro-growth policies. On the other hand, Chilean-type controls on inflows help to discourage speculative capital inflows and promote stability (Eichengreen, 1999; Stiglitz, 1999). They also reduce macroeconomic volatility and increase consumer welfare (Jeanne and Korinek, 2010). Analyzing *KCi* and *KCo* separately perhaps reveals differed effect on CID volatility. Second, it is to ensure the robustness of results. KC index is compiled as the average of *KCi* and *KCo*. If *KC* is estimated significantly, either *KCi* or *KCo* or both should be significant to support the robustness of *KC* results. Regarding the robustness check, in addition to *KCi* and *KCo*, we use a *de facto* measurement for capital controls in section 6.2.

Vector X_t contains other relevant factors that potentially affect the volatility of RMB CID. These factors include some domestic macroeconomic factors, namely, China's GDP growth and increase in trade openness (Cheung and Qian, 2011; Dooley and Isard, 1980), a liquidity factor, the NDF bid–ask spread (Cantú, 2019; Frankel et al., 2002), some financial stability factors, such as the appreciation of the RMB nominal effective exchange rate (NEER) and RMB exchange rate volatility, and a global factor, the VIX index that gauge the global financial risk. Additionally, four dummy variables are used to capture four important economic and policy regime changes: *GFC* and *QE* to capture the effect of the 2008 financial crisis and the Fed's QE policy, respectively, and *Reform2005* and *Reform2015* to capture China's liberalization of the RMB exchange regime through the two exchange rate reforms in July 2005 and August 2015, respectively. To ensure the robustness, in Section 6, we use alternative measurements of the exchange rate regime, for example, a 0–7 ranking index variable that measures the level of liberalization of the RMB exchange rate (Appendix Table A2).

Recent studies suggest that capital controls and exchange rate regimes act as buffer for emerging market economies to insulate external shocks and sustain financial stability. For example, Han and Wei (2018) suggest a “2.5 lemma” postulation under which a flexible exchange rate regime alone yields a periphery country monetary autonomy when the center country increases its interest rate, while capital controls can insolate monetary policy shocks when the center country lowers its interest rate. Edwards and Rigobon (2009) argue that the estimate for the effectiveness of capital controls is biased if the interaction between the targeted exchange rate regime and capital controls is not considered.

In addition to the liberalization of its exchange rate regime discussed in section 3.1, China appears to experience a change in monetary policy autonomy stance. As shown in Figure 2, China apparently shifted to a more independent monetary policy stance after the 2008 financial crisis when the Fed implemented its QE policy. Thus, it is conceivable that RMB CID volatility responds differently to capital controls under a new monetary policy stance than they did previously. The 2008 global financial crisis wracks havoc on the global financial market and it is the direct reason leading to Fed’s QE policy. It is possible that capital controls change its way to affect RMB CID volatility during the 2008 financial crisis. To account for these possibilities, we add an interaction term of capital controls and time dummy variables for QE and GFC, *QE* × *KC* and *GFC* × *KC*.

Drawing on these arguments, we add terms for the interaction of capital controls, exchange rate regime, monetary policy regime and the global financial crisis, for example, *Reform2005* × *KC*, *Reform2015* × *KC*, *QE* × *KC*, and *GFC* × *KC* in Equation (1). The regression therefore is:

$$VCID_t = c + \sum_{p=1} \alpha_p \ VCID_{t-p} + \beta\ KC_t + \gamma\ Rgm + \theta\ Rgm \times\ KC_t + X_t' \ \varphi + \varepsilon_t \qquad (2)$$

where Rgm includes *Reform2005*, *Reform2015*, *QE*, and *GFC*. A significant estimation for θ indicates the volatility of RMB CID reacts to capital controls differently under different exchange rate regimes and monetary policy stances.

To avoid the possibility of missing important determinants, we aim to include all abovementioned variables in the regression. However, given the lack of degrees of freedom and without diminishing the statistical properties of the key determinants owing to the inclusion of many insignificant variables, we sequentially drop the most insignificant variables one by one until only significant variables remained in the final regression[9]. Another motivation to use the approach of sequentially dropping insignificant variables is that we try to let data speak for themselves. Since the literature lacks of prior information about what determines the CID volatility, we experiment each possible variable and consider an insignificant one to be irrelevant and dropped out from our regression. All independent variables enter in the regressions in contemporaneous form, because we consider the volatility of CID a financial factor that responds instantly to a change of their determinants[10].

To identify the possible channel through which KC affects CID volatility, we study how capital controls affect the volatility of IRD and FP[11], separately. The regressions are specified as:

$$IRD_t = c + \sum_{p=1} \alpha_p \; IRD_{t-p} + \beta \, KC_t + \gamma \, Rgm + \theta \, Rgm \times \; KC_t + Y_t' \, \varphi + \varepsilon_t \qquad (3)$$

$$FP_t = c + \sum_{p=1} \alpha_p \; FP_{t-p} + \beta \, KC_t + \gamma \, Rgm \; + \theta \, Rgm \times \; KC_t + Z_t' \, \varphi + \varepsilon_t \qquad (4)$$

where IRD_t and FP_t are the dependent variables. The IRD mainly reflects the monetary policy differential between China and the US. In other words, it indicates whether China's monetary policies are independent from those of the U.S. Fed's. FP represents the market expectation of the RMB exchange rate valuation. Therefore, capital controls may affect IRD and FP in different ways, through which capital controls further affect the CID volatility overall. The overall impact of capital controls on CID volatility is the combined effect on IRD and FP volatility if capital controls affect IRD and FP in the same direction. However, if capital controls create opposite impacts on the volatility of IRD and FP, their tradeoff is the net effect of capital controls on CID volatility. KC_t are capital controls and Rgm contains *Reform2005*, *Reform2015*, *QE* and *GFC*. We expect that capital controls affect the volatility of IRD and FP differently under different RMB exchange rate regime and monetary policy stance. The control variables in Y_t and Z_t may be different. All control variables in Y_t and Z_t are selected from all possible

[9] See Cheung et al. (2016) for details.
[10] For purposes of robustness, we performed the regressions using lagged variables as the predetermined variables, i.e. a ARDL(p, q) regression. The results, for the most part, remained the same. The results are available upon request.
[11] Cheung and Qian (2011) studied the behavior of the RMB CID by separating the RMB CID into the IRD and FP. They found that explanatory factors mainly affect the CID through the FP rather than the IRD component.

control variables discussed in equation (1). The final selection depends on the process to sequentially drop most insignificant variables.

4. Empirical results analyses

To gain a general understanding about how capital controls are associated with the volatility of the CID, we first compare a pair of CIDs from selected currencies that are subject to capital controls (Chinese RMB and Korean won, KRW) with another pair that is free from capital flow restrictions (Japanese yen, JPY, and Canadian dollar, CAD). Figure 3 shows that both the level and volatility of the CID of RMB and KRW are remarkably higher than those of the CID of JPY and CAD. Quantitatively, as the Table 1 summary statistics show, the two currencies with capital controls have a CID level that is, on average, eight times higher than those currencies that are free of capital restrictions and 11 times more volatile in terms of the CID standard deviation. The comparison of cross-country data suggests that capital controls and CID volatility are positively associated. This simple data comparison is useful, but it does not reveal how capital controls affect the volatility of the CID. For this investigation, we now turn to the regression analysis.

4.1 Capital controls and RMB CID volatility

Columns (1) and (2) of Table 2 reports results of the baseline model equation (1) and equation (2) where interaction terms, *Reform2005×KC*, *Reform2015×KC*, *QE×KC*, and *GFC×KC* are added to examine how capital controls affect the volatility of the RMB CID. Since equation (2) explains twice more variation of CID volatility than equation (1) (i.e. the R^2 is 0.28 versus 0.128), we focus on column (2) to interpret results. The coefficient of the capital control variable (*KC*) is estimated as 0.13, significant at 10%; that is, a one-level increase in the strictness of China's capital controls leads to 0.13 more volatility in the RMB CID. Specifically, a one standard deviation tighten-up in China's capital controls raises about one standard deviation of volatility of RMB CID. The result suggests China's capital controls have a both statistically and economically important effect on RMB CID volatility. Indeed, capital controls that limit the mobility of capital flows help to insulate an economy from external shocks and stabilize its financial market, but at the same time, they reduce financial market liquidity, thereby causing higher volatility (Cantú, 2019; Frenkel et al., 2002). Our finding points out an externality of capital controls that a country utilized as a macro-prudential tool. On one hand, capital controls make the domestic financial market resilient to financial shocks; on the other hand, they reduce the efficiency of the financial market to move capitals freely, causing volatility and instability in financial market.

Regarding exchange rate regime interaction terms, only *Reform2015×KC* is estimated to be significantly positive. *Reform2005×KC* is insignificant and consequently, is dropped from the regression. Because the RMB exchange rate regime after the 2015 reform is more liberalized than that after the 2005 reform, with the latter being a *de facto* peg to the USD (Goldstein and Lardy, 2006; Prasad and Wei, 2005), our results suggest that capital controls cause higher CID volatility in a more liberalized exchange rate regime.

The effect of the capital controls during the Fed's QE (*QE×KC*) is negative and significant, suggesting that during the era of global monetary expansion, China's capital controls can weather the surge of capital inflows and shield the country from external monetary policy spillover to reduce financial market volatility (Han and Wei, 2018). A plausible channel for this volatility-mitigating effect of capital controls is China's shift to a more independent monetary policy during the QE era, for which we provide more evidence in Table 3. Regarding to the 2008 global financial crisis, the results indicate that there is higher volatility of the RMB CID during the crisis [See columns (2) and (3)]. However, the way that capital controls affect RMB CID volatility is not significantly different from tranquil times as *GFC×KC* is not significantly estimated thus dropped out of the regression.

Based on BIC inference, we include three lags of the dependent variable, all of which we estimate to be significantly negative[12]. The result perhaps suggests the existence of long-term volatility (Anderson and Bollerslev, 1997), in which the CID volatility in previous months converges to the latent long-run volatility. Our result indicates that it takes 3 months for RMB CID volatility to converge. We return to this argument of long-run volatility in Section 5.

An increase in NDF spread is found to be associated with a higher CID volatility. This is in line with the arguments of Cantú (2019) and Frenkel et al. (2002)—that shallow market liquidity

[12] By contrast, the lagged dependent variable is not significant in column (1) where no interaction term is included. The different results on the lagged dependent variable suggest the importance of RMB exchange rate regime and monetary policy stance in explaining the variation of CID volatility. In fact, with interaction terms, the regression model (2) has more than two times explanatory power than the regression (1) without interaction terms.

leads to a more volatile market. The official RMB exchange rate volatility, which directly measures the stability of the RMB exchange rate system, is positively associated with CID volatility. Thus, a less stable RMB exchange rate translates into an expectation of high RMB exchange rate volatility in the future, leading to a more volatile RMB CID.

We find that the RMB CID was more volatile during the 2008 global financial crisis and in the “controlled floating” exchange rate regime after August 2015. These results are consistent with the data pattern shown in Figure 1. The Fed’s QE is associated with a low volatility of RMB CID. A plausible explanation for this effect again is that China’s monetary policymaking become more independent from the Fed’s during the QE periods to resist the spillover effect (Chang et al., 2015; Goldstein and Lardy, 2006). The light gray shade area in Figure 1 shows that RMB CID is relatively stable during QE periods.

Considering how the controls on inflows and outflows work differently, we report *KCi* and *KCo* results in columns (3) and (4) of Table 2, respectively. Column (3) shows similar results as those in column (2), whereas the results for *KCo* in column (4) differ from both *KC* and *KCi* in the following four aspects. 1) *KCo* has a statistically insignificant effect on CID volatility other than during QE periods and in the more flexible exchange rate regime after 2015, where it produces a stronger amplification effect than both *KC* and *KCi*. 2) There are two lags of independent variables that are significant, compared to three significant lags in columns (2) and (3). 3) ΔNEER reduces the CID in the presence of *KCo* or *KCi*, which is probably because the currency appreciation reduces investors’ expectations of further appreciation, thereby stabilizing the exchange rate. 4) The global fear gauge, VIX, is positive and significant at 1%, indicating that, although capital controls help shield a country from some external shocks, when global financial markets experienced turmoil, the Chinese market was not immune to the resulting global shock waves (Edwards, 1999).

4.2 Capital controls and the volatility of IRD and FP

As previously stated, the RMB CID is comprised of two components, the IRD and FP. Stability of the IRD reveals the resilience of the Chinese domestic money market while high volatility of the FP indicates low efficiency of the RMB exchange market. Thus, separated analysis of the IRD and FP may reveal the channel through which capital controls affect the volatility of the RMB CID and financial stability, that is, whether and how they operate through the channel of monetary market spillover, or exchange market volatility, or both.

Table 3 reports the results for IRD volatility. In column (1), we show that capital controls are positively associated with IRD volatility before the Fed's QE policies took effect; however, the effect reverses during the Fed's QE era, suggesting substantial changes in China's monetary policy making process and in the use of capital controls to maintain monetary and financial stability. In Figure 2, we plot the 3-month Chibor rate and the USD Libor rate; the plot shows the clear departure of the RMB interest rate from the US interest rate after the onset of the Fed's QE policy during the 2008 financial crisis. A plausible explanation is that, as the Mundell–Fleming trilemma theory suggests, equipped with capital controls, the People's Bank of China was able to choose a policy with greater monetary policy autonomy in order to shield China from the possible adverse effects of the Fed's extreme expansive monetary policy. Indeed, Davis and Presno (2017) found that capital controls allow an optimal monetary policy to be focused less on foreign interest rates and more on domestic stabilization.

We estimate that the one-lagged dependent variable has a positive and significant coefficient. High GDP growth and rising trade openness, two macroeconomic variables that measure the overall strength of the Chinese economy, are positively associated with IRD volatility. It is possible that the strengthening economy gave the Chinese central bank more space to maneuver with respect to its interest rate policies. IRD volatility is higher after the 2005 exchange rate reform, which is consistent with other scholars' observations that both monetary policies and intervention were used to maintain the exchange rate stability after the 2005 reform (Cheung et al., 2018; Prasad and Wei, 2005).

Columns (2) and (3) of Table 3 show that the controls on inflows and outflows have similar effects on IRD volatility during the QE era as overall controls do; however, the *KCo* effect is not significant before QE and weaker than that of *KCi* during the QE period.

Table 4 shows the results of how capital controls affect FP volatility. The FP volatility directly reflects the stability of the expected RMB exchange rate. According to Zhang (2003), quantitative and administrative controls were often implemented on the exchange rate between the RMB and foreign currencies to maintain RMB stability. However, we find that capital controls do not affect FP volatility during the "hard peg" periods before 2005. Rather, they significantly amplify the volatility of FP during relatively liberalized "crawl peg" (between July

2005 and August 2015) and "controlled floating" regimes (after August 2015). Further, this volatility amplification effect becomes more prominent when the RMB exchange rate is more flexible. For example, a one-unit increase in capital controls is associated with 1.06 more FP volatility during the "controlled floating" regime, but only 0.11 during "crawl peg" periods. It is possible that investors expect a wider fluctuation of exchange rate during a more flexible regime than that during a less flexible regime where the magnitude of the exchange rate change is limited, for example, by the daily exchange rate bands. Thus, when capital controls restrict capital flows and cause less liquidity in the foreign exchange market, the volatility of the exchange rate tends to increase (Cantú, 2019; Frenkel et al., 2002).

Compared across the QE results in Tables 3 and 4, Table 3 shows that the volatility of the IRD is mainly influenced by the QE policy spillover, whereas Table 4 shows that the Fed's QE policies have no influence on FP volatility (i.e. interaction terms between QE and *KC*, *KCi*, and *KCo* are all insignificant and thus dropped from regressions). On the other hand, while Table 3 reports no effect of exchange rate regime to the IRD volatility, the exchange rate regime reform in 2015 is found to significantly increase the FP volatility in Table 4. These different results perhaps reflect the fact that the Fed's policy spillover effect mainly passes through the monetary channel (IRD) as opposed to the foreign exchange channel (FP).

The coefficients for the three lagged dependent variables are negative and significant [see column (1) of Table 4]. It is possible that FP volatility has long-run memory. In addition, consistent with the results in Table 2, the offshore liquidity measurement (ΔNDF spread) and exchange rate volatility are positively associated with FP volatility; so are ΔNEER and VIX when capital controls on capital outflows are considered.

In columns (2) and (3) of Table 4, both *KCi* and *KCo* amplify FP volatility during the regime of "controlled floating." It appears that, although China was liberalizing its exchange rate, it still tightly controlled its capital account capital flows. Faced with market turmoil and skepticism about its exchange rate policy move, China did not hesitate to assert its resolute intolerance of market volatility and resorted to administrative measures and control policies to restore stability (Cheung et al., 2018). For instance, China abruptly intervened the (onshore and offshore) RMB market and equity market in 2015, when China experienced a substantial amount of capital flowed out of its economy.

Based on the analysis on the effect of capital controls on IRD and FP volatility separately in Tables 3 and 4, we can summarize the overall effect of capital controls on CID volatility, which works through different channels: the monetary market channel (IRD) and the foreign exchange market (FP). Our study suggests that the overall effect of capital controls on RMB CID volatility before the Fed's QE is the combined amplification effect of capital controls on both IRD and FP volatility; however, after QE and when China gradually liberalized its exchange rate regime, the effect is a net effect resulting from the tradeoff between the mitigating effect of capital controls on IRD volatility and the amplification effect on FP volatility. Overall, these results are in accordance with the findings of Funke et al. (2015). However, we demonstrate a more complex mechanism (e.g., the tradeoff between a pair of opposite effects) through which capital controls impact RMB CID volatility.

5. Capital controls and CID volatility in the long run

Andersen and Bollerslev (1997) argue that financial market volatility comprises long-run and short-run volatility. The long-run dependence is best characterized by a slowly mean-reverting fractionally integrated process while much shorter-lived volatilities are typically observed with high-frequency intra-daily returns. Following these authors, we hypothesize that RMB cross-border arbitrage market volatility contains latent long-run volatility. Indeed, the negative and significantly estimated lagged dependent variables shown in Table 2 perhaps suggest that it takes a few months for the monthly CID volatility to gradually converge to the latent long-run volatility.

Interestingly, Eichengreen and Rose (2014) find that capital controls are durable; once installed, their effect is long lasting. Is there any association between long-lasting capital controls and the long-run volatility of the RMB CID? If so, do they comove or diverge? Moreover, how does the change in capital controls impact short-run CID volatility?

To answer these questions, we utilize an ECM that allows to study the long-run and short-run volatility of the CID simultaneously without arbitrarily separating data into long-run and short-run variance.

The ECM model is specified as

$$\Delta VCID_t = c + \alpha(VCID_{t-1} - \beta KC_{t-1}) + \gamma Rgm + \rho\Delta KC_t + \theta Rgm \times \Delta KC_t + X_t'\varphi + \varepsilon_t \qquad (5)$$

where $\Delta VCID_t$ is the first difference of unconditional variance of the RMB CID. The error correction term, $(VCID_{t-1} - \beta KC_{t-1})$, represents the long-term relationship between CID volatility and KC, with β measuring the direction and degree of their long-term relationship. A positive β indicates the comovement in their long-term relation; If it is negative, they diverge from each other in long run. The monthly CID volatility adjusts to the long-term relationship at a pace of α. The estimate for ρ represents the association between the change of KC and $\Delta VCID$ (the short-term association). Rgm and X_t are the same as in equation (2).

The significant results reported in Table 5 confirm that there is long-run dependency between CID volatility and capital controls, regardless the measurements of capital controls. According to our estimate, the average slope of the long-term linear relationship between CID volatility and *KCs* (*KC*, *KCi*, and *KCo*) is 0.038—that is, in the long term, a one-unit increase in the level of *KC* is associated with 0.038 more volatility in the CID. They comove in long run. Considering the short-term interaction, the results shows that the change of the capital control level (ΔKC, ΔKCi, and ΔKCo) shocks up the short-run CID volatility ($\Delta VCID$). Specifically, a one-unit increase in the change of capital control level (ΔKC, ΔKCi, and ΔKCo) is associated with, on average, a 0.037 greater change of CID volatility ($\Delta VCID$). The estimate for the error correction term, α, is close to 1 and significant in all three regressions. The result suggests that the short-term deviation from the long-term relation between CID volatility and capital controls converges to their long-run relation in one month.

The bound test of Pesaran, Shin, and Smith (2001) is performed for each regression; the test results confirm the existence of a long-run association between capital controls and RMB CID volatility. Compared to Table 2, separating the long run and short run in Table 5 reveals some extra dynamics of CID volatility and capital controls—China's capital controls and the CID volatility might not only be positively associated in the long term, but also interact during short-term fluctuations. In addition, the ECM model separating long-run and short-run volatility explains the variance of CID better than the ARDL model does in Table 3 (i.e., average adjusted R^2 is 0.50 vs. 0.31).

Next, we study the long-run and short-run volatility of the IRD and FP separately in Tables 6 and 7, in which we discover some contrasting dynamics. First, in accordance to the results in Table 5, capital controls significantly affect IRD volatility in both the long run and short run, but they exert neither long-run nor short-term influence on FP volatility, except that capital controls outflows amplify the FP volatility after 2015 reform (column 3 of Table 7).

Second, in the long run, capital controls are positively associated with IRD volatility (Table 6) but have no significant association with FP volatility (Table 7). IRD volatility converges to the long-run association slower than FP volatility does, which tends to adjust to long-run relation in next month[13] (coefficient of the error correction term is close to 1). This is consistent with the fact that the exchange rate market is a more volatile than money market.

Third, in the short-run relationship, a change in the level of capital controls is positively associated with a change in volatility in the IRD but not the FP volatility.

Fourth, capital controls on capital inflows and outflows appear to affect the short-run volatility of FP differently (Table 7). In general, controls on both inflows and outflows do not exert a significant effect on the short-run FP volatility, but during "controlled floating" periods, outflow controls substantially increase the short-run FP volatility, whereas inflow controls have no significant influence.

Finally, regarding other economic factors affecting the change in volatility of both the IRD and FP, both the increase in NDF spread and nominal exchange rate volatility positively affect the change of both IRD and FP volatility; the appreciation of RMB (ΔNEER) negatively affect the change of FP volatility only; the global fear factor, VIX, seems to affect the change of FP volatility, rather than the IRD, in a push-up fashion. Overall, the ECM model explains FP volatility better than it does IRD volatility (the average adjusted R^2 is 0.58 vs. 0.29).

6. Discussion and robustness check

In this section, we conduct robustness checks for our main findings presented in Section 4. These additional analyses include an alternative measurement of the RMB exchange rate regimes, a *de facto* measure of capital controls, an alternative forward hedge market rate, and the conditional volatility of the CID extracted from GARCH model.

6.1 An alternative measure for the RMB exchange rate regime

[13] Frenkel et al. (2002) examined the effect of capital controls in a theoretical model that combines a monetary model of exchange rate determination and a theory of real capital stock formation. They found that the short-term adjustment process of the exchange rate to the implementation of capital controls that act as a Tobin tax exhibits Dornbusch overshooting characteristics (Frenkel et al., 2002, p. 16).

In Section 4, we measure RMB regime changes using simple time dummy variables, namely, *Reform2005* and *Reform2015*. However, China has implemented its exchange rate liberalization process gradually throughout our sample periods. For example, since July 2005, China has slowly but consistently expanded the RMB daily trading band from ±0.3%–0.5% to ±1%–±2%, and to a daily central parity determined by the market value of the previous day. To capture this gradual dynamic in exchange rate liberalization, we construct a ranking index variable (*RMB exch libr*) to measure the change of RMB exchange rate flexibility from 0 to 7. A high value of *RMB exch libr* indicates a policy with greater liberalization and a more flexible RMB exchange rate. Detailed information about the *RMB exch libr* variable is provided in Appendix Table A2.

We replace the *Reform2005* and *Reform2015* variables with the newly constructed variable, *RMB exch libr,* and re-run the regressions in Table 2 to check the sensitivity of our results[14]. The results, shown in Table 8, are comparable to those in Table 2. Although the results report no significant effect of capital controls in general, we find that they increase the CID volatility when the liberalization of exchange rate regime increases. As in Table 2, QE policy is found to reduce the volatility of CID. These results remain when capital controls on inflows and outflows are used in regressions, except that *KCi* is estimated significantly positive in column (2). Judging from the adjusted R^2, the model using a ranking index variable to measure the exchange rate regime seems to explain the relationships less well than the model using time dummy variables (Table 2).

6.2 De facto measure of capital controls

Chen and Qian's (2016) index is a *de jure* measurement of the restrictiveness of capital controls, which might suffer measurement mismatch if capital control policies are not implemented effectively. One way to deal with this issue is to use a *de facto* measurement. A commonly used *de facto* capital control measure is the level of the CID itself (Frankel, 1992; Levich, 2017; Ma and McCauley, 2008). A positive CID suggests that capital controls effectively prevent capital inflows to arbitrage off the deviation from the CIP—the larger is the positive CID, the more effective and tightly restrictive are the capital controls on inflows. Meanwhile, the

[14] To save space, we do not report our robustness checks on our IRD and FP results, which are available upon request.

larger is the negative CID, the more restrictive are the capital controls on capital outflows (Ma and McCauley, 2008). To capture the overall *de facto* effectiveness of China's capital controls, we use the absolute value of the CID.

The results of our analyses, in which we replace the Chen and Qian (2016) *de jure* index with the absolute value of the RMB CID, are reported in Table 9. As shown in column (1), *de facto* capital controls are significantly estimated, suggesting that capital controls increase the volatility of the RMB CID. In addition, we interact the *de facto KC* with exchange rate regime dummies. The significant estimation of *Reform2015* × *Absolute CID* suggests that capital controls amplify the volatility of the CID during the more liberalized RMB exchange rate regime. This is consistent with the findings in Table 2. However, we do not estimate that the de facto capital control itself is significant. Overall, regressions that use *de facto* measurement for capital controls in this section do not exactly replicate the results in Table 2. However, they confirm that there is a stronger amplification effect of capital controls on CID volatility in a more liberalized exchange rate regime.

6.3 Using offshore deliverable forward

In Section 4, we use the RMB NDF rates to compute the CID. The NDF rates, which are determined in the deep, liquid offshore market, are the results of the interplay between market forces, and may be interpreted as a market proxy for the expected future Chinese RMB exchange rate (Cheung and Qian, 2011). However, the offshore RMB NDF has become thin in liquidity since 2010. A probable reason is the creation and rapid development of the offshore RMB (dubbed "CNH") spot and deliverable forward market in Hong Kong since 2010. The CNH increasingly challenges the NDF market in terms of its growing daily turnover and other advantages (McCauley et al., 2014), including the low implied volatility in the CNH market and investors' preference for the CNH market over the NDF market. For this reason, we generate an alternative CID by replacing the 3-month NDF rate with the 3-month CNH deliverable forward. The data samples are from October 2010 to December 2016 owing to data availability issues. As both the NDF and CNH forward markets are offshore, and thus, are free of capital controls, we expect them to yield similar results.

The CNH implied CID volatility results, reported in Table 10, largely confirm our main result, that capital controls amplify the volatility of the RMB CID, except that the estimate for inflow controls (*KCi*) is insignificant. Similar as the results in Table 2, this amplification effect of capital controls on CID volatility intensifies when the RMB became more flexible under the "managed floating" exchange rate regime. These results hold regardless of measurements for overall capital controls, controls on inflows, or controls on outflows.

6.4 GARCH-based conditional volatility

In addition to using unconditional volatility of the CID calculated using daily data, some researchers have used the estimated volatilities of a GARCH (1, 1) model (Bollerslev, 1986) to study the association between capital controls and exchange rate volatility (Edwards and Rigobon, 2009; Funke et al., 2015). Following these approaches, we first fit a GARCH (1,1) model of the CID to obtain the conditional volatility of the CID; then, we use ARDL regression to estimate how China's capital controls affect the conditional volatility of the RMB CID.

Table 11 shows the results. The positive impacts of capital controls on CID volatility are robust to the use of the conditional variance of CID. The more flexible exchange regime is associated with greater conditional volatility, and the Fed's QE policy creates a spillover effect, thereby reducing the conditional volatility of the CID. Both exchange rate regime and QE policy alter the impact of capital controls on the conditional volatility of the RMB CID; while the more flexible exchange regime increases the amplification effect of capital controls on CID volatility, the QE policy appears to muffle this amplification effect. All these results are similar as those in Table 2, except that now only VIX affects the conditional volatility of the RMB CID and the lagged dependent variable turns positive. This is consistent with the characteristics of conditional variance data generated from the GARCH process.

7. Concluding remarks

In the current global environment, capital controls are back (Eichengreen and Rose, 2014), owing to their role in insolating external financial shocks and helping to sustain EMs during times of financial crisis. This is particularly true during the 2008 global financial crisis (Ostry et al. 2010).

Under this backdrop, we analyzed capital controls' effects on the volatility of the RMB CID. Using Chinese monthly data, we found that capital controls lead to more volatile RMB CID. To the best of our knowledge, the current study fills a gap in capital controls and the CID literature, in which the studies on how capital controls affect the volatility of the CID are rare.

While capital controls may enhance China's financial stability, they are found to create volatility of the RMB CID. In this sense, capital controls distort capital flows and hinder the efficiency of financial markets. A volatile RMB CID leads to volatile illicit cross-border capital flows, which jeopardize the stability of the Chinese financial system. Thus, China's capital controls, while playing a positive role, may impose a negative externality on China's financial stability. This finding highlights the tradeoff between the dual role of capital controls in enhancing financial stability and hindering financial market efficiency.

The role of capital controls in affecting RMB CID volatility depends on the RMB exchange rate regime. The impact of capital controls is substantially higher during the relatively more liberalized RMB exchange rate regime, especially after the reform in August 2015, than RMB hard peg periods. In addition, the Fed's QE policies have a spillover effect on the role of capital controls in RMB CID volatility. Our study indicates that China's capital controls reduce the volatility of the RMB CID during the QE era, primarily through the channel of diminishing the volatility of the IRD. The volatility of the FP, another component of the CID, is amplified by capital controls when the RMB exchange rate regime is more liberalized.

This study also contributes to the existing literature by investigating how capital controls affect the long-run and short-run volatility of the RMB CID. An ECM regression allows us to analyze both the long-run and short-run volatility simultaneously, by which we find evidence that capital controls positively affect both long-run and short-run volatility of the CID. Capital controls are positively associated with both long-run and short-run volatility of the IRD, whereas they do not significantly impact FP volatility in the long run and only affect short-run FP volatility in "controlled floating" exchange rate regime.

Our study is among the growing works on capital controls as a viable tool for macro-prudential policy. However, we depart from other studies by scrutinizing a possible negative externality of capital controls—the possibility of creating volatility and hindering the efficiency of the financial market by limiting the mobility of capital flows and reducing financial market liquidity and efficiency, eventually leading to possible instability of the financial market. Given that China continuously implements its capital control policy, China needs to balance the tradeoff effect between the role of capital controls in enhancing financial stability and reducing financial market efficiency.

References

Andersen, T.G., Bollerslev, T., 1997. Heterogeneous information arrivals and return volatility dynamics: Uncovering the long-run in high frequency returns. The Journal of Finance 52(3), 975-1005.

Benigno, G., Chen, H., Otrok, C., Rebucci, A., Young, E. R., 2016. Optimal capital controls and real exchange rate policies: A pecuniary externality perspective. Journal of Monetary Economics 84, 147-165.

Bollerslev, T., 1986. Generalized autoregressive conditional heteroskedasticity. Journal of Econometrics 31(3), 307-327.

Federal Reserve Bank, 2014. Federal Reserve issues FOMC statement. Board of Governors the Federal Reserve System, Washington D.C.

Calderón, C., Kubota, M., 2018. Does higher openness cause more real exchange rate volatility? Journal of International Economics 110, 176-204.

Chang, C., Liu, Z., Spiegel, M.M., 2015. Capital controls and optimal Chinese monetary policy. Journal of Monetary Economics 74, 1-15.

Cantú, C., 2019. Effects of capital controls on foreign exchange liquidity. Journal of International Money and Finance 93, 201-222.

Chen, J., Qian, X., 2016. Measuring on-going changes in China’s capital controls: A de jure and a hybrid index data set. China Economic Review 38, 167–182.

Chen, S., Chang, M.J., 2015. Capital control and exchange rate volatility. The North American Journal of Economics and Finance 33, 167-177.

Cheung, Y.W., Herrala, R., 2014. China's capital controls: through the prism of covered interest differentials. Pacific Economic Review 19(1), 112-134.

Cheung, Y.W., Qian, X., 2010. Capital flight: China's experience. Review of Development Economics 14, 227-247.

Cheung, Y.W., Qian, X., 2011. Deviations from covered interest parity: the case of China. The Evolving Role of Asia in Global Finance, Emerald Group Publishing Limited, 369-386.

Cheung, Y.W., Steinkamp, S., Westermann, F., 2016. China's capital flight: Pre- and post-crisis experiences. Journal of International Money and Finance 66(C), 88-112.

Cheung, Y.W., Hui, C.H., Tsang, A., 2018. The RMB central parity formation mechanism: August 2015 to December 2016. Journal of International Money and Finance 86, 223-243.

Chinn, M.D., Ito, H., 2008. A new measure of financial openness. Journal of Comparative Policy Analysis 10(3), 309–322.

Choi, K., Yu, W.C., Zivot, E., 2010. Long memory versus structural breaks in modeling and forecasting realized volatility. Journal of International Money and Finance 29(5), 857-875.

Davis, J. S., Presno, I., 2017. Capital controls and monetary policy autonomy in a small open economy. Journal of Monetary Economics 85, 114-130.

Dooley, M.P., Isard, P., 1980. Capital Controls, Political Risk, and Deviations from Interest Rate Parity. Journal of Political Economy 88(2), 370-84.

Edwards, S., 1998. Interest rate volatility, capital controls, and contagion. National Bureau of Economic Research No. w6756.

Edwards, S., 1998b. Interest Rate Volatility, Contagion and Convergence: An Empirical Investigation of the Cases of Argentina, Chile and Mexico. Journal of Applied Economics 1(1), 55-86.

Edwards, S., 1999. How effective are capital controls? Journal of Economic Perspectives 13(4), 65-84.

Edwards, S., 2007. Capital controls, capital flow contractions, and macroeconomic vulnerability. Journal of International Money and Finance 26, 814-840.

Edwards, S., Rigobon, R., 2009. Capital controls on inflows, exchange rate volatility and external vulnerability, Journal of International Economics 78(2), 256-267.

Eichengreen, B.J. 1999. Toward a new international financial architecture: A practical post-Asia agenda. Peterson Institute Press: All Books.

Eichengreen, B.J., Rose, A., 2014. Capital controls in the 21st century. Journal of International Money and Finance 48(Part A), 1-16.

Elliott, G., Rothenberg, T.J. and Stock, J.H., 1996. Efficient Tests for an Autoregressive Unit Root. Econometrica: Journal of the Econometric Society, pp.813-836.

Engle, R., 2001. GARCH 101: The use of ARCH/GARCH models in applied econometrics. Journal of economic perspectives, 15(4), 157-168.

Farhi, E., Werning, I., 2014. Dilemma not trilemma? Capital controls and exchange rates with volatile capital flows. IMF Economic Review 62(4), 569-605.

Fernandez, A., Klein, M.W., Rebucci, A., Schindler, M., Uribe, M., 2016. Capital control measures: A new dataset. IMF Economic Review 64(3), 548-574

Frankel, J.A., 1992. Measuring international capital mobility: A review. The American Economic Review 82(2), 197-202.

Frankel, J.A., 2009. New estimation of China's exchange rate regime. Pacific Economic Review 14 (3), 346–360.

Frenkel, M., Shimidt, G., Stadtmann, G., Christiane, N., 2002. The effects of capital controls on exchange rate volatility and output. International Economic Journal 16(4), 27-51.

Funke, M., Shu, C., Cheng, X., Eraslan, S., 2015. Assessing the CNH–CNY pricing differential: Role of fundamentals, contagion and policy. Journal of International Money and Finance 59, 245-262.

Goldstein, M., Lardy, N., 2006. China's exchange rate policy dilemma. American Economic Review 96(2), 422-426.

Han, X., Wei, S.J., 2018. International transmissions of monetary shocks: Between a trilemma and a dilemma. Journal of International Economics 110, 205-219.

IMF, 2011. Recent experiences in managing capital inflows-Cross-cutting themes and possible policy framework. International Monetary Fund, Washington, D.C.

IMF, 2012. The liberalization and management of capital flows: An institutional view. International Monetary Fund, Washington, D.C.

IMF, 2013. Guidance note for the liberalization and management of capital flows. International Monetary Fund, Washington, D.C.

Ito, T., 1983. Capital Controls and Covered Interest Parity, NBER Working Paper No. 1187.

Jeanne, O., Korinek, A., 2010. Excessive volatility in capital flows: A pigouvian taxation approach. American Economic Review 100(2), 403-407.

Keynes, J. M., 1923. A Tract on Monetary Reform, London: Macmillan.

Korinek, A., Sandri, D., 2016. Capital controls or macroprudential regulation? Journal of International Economics 99, S27-S42.

Krugman, P., 1998. Saving Asia: It's time to get radical. Fortune 138(5), 74-80.

Levich, R., 2017. CIP then and now: A brief survey of measuring and exploiting deviations from covered interest parity, paper for BIS symposium: CIP-RIP? Bank for International Settlements.

McCauley, R., Shu C. and Ma, G., 2014. Non-deliverable forwards: 2013 and beyond. BIS Quarterly Review March.

Ma, G., McCauley, R.N., 2008. Efficacy of China's capital controls: Evidence from price and flow Data. Pacific Economic Review 13(1), 104-123.

Ma, G., McCauley, R.N., 2011. The evolving renminbi regime and implications for Asian currency stability. Journal of the Japanese and International Economies 25(1), 23-38.

Ma, J., 2016. RMB Rate to Depend More on Basket of Currencies: PBOC Economist. http://news.xinhuanet.com/english/2016-01/12/c_134999156.html.

Magud, N.E, Reinhart C.M., and Rogoff K.S., 2018. Capital Controls: Myth and Reality--A Portfolio Balance Approach. Annals of Economics and Finance, Society for AEF, vol. 19(1), pages 1-47.

Montecino, J.A., 2018. Capital controls and the real exchange rate: Do controls promote disequilibria? Journal of International Economics 114, 80-95.

Mundell, R., "Capital Mobility and Stabilization Policy under Fixed and Flexible Exchange Rates," Canadian Journal of Economics and Political Science 29 (1963), 475–485.

Ostry, J.D., Ghosh, A.R., Habermeier, K., Chamon, M., Qureshi, M.S., Reinhardt, D., 2010. Capital inflows: The role of controls. Revista de Economia Institucional 12(23), 135-164.

Ostry, J.D., Ghosh, A.R., Habermeier, K.F., Laeven, L., Chamon, M., Qureshi, M.S., Kokenyne, A., 2011. Managing capital inflows: What tools to use? Staff discussion paper, International Monetary Fund, Washington, D.C.

Ostry, J.D., Ghosh, A.R., Chamon, M., Qureshi, M.S., 2012. Tools for managing financial - stability risks from capital inflows. Journal of International Economics, 88, 407-421.

Pesaran, M.H., Shin, Y., Smith, R.J., 2001. Bounds Testing Approaches to the Analysis of Level Relationships. Journal of Applied Econometrics 16 (3), 289-326.

People's Bank of China, 2015. The PBC Announcement on Improving Quotation of the Central Parity of RMB against US Dollar. http://www.pbc.gov.cn/english/130721/2941603/index.html

Prasad, E., Wei, S. J., 2005. The Chinese approach to capital inflows: patterns and possible explanations. NBER Working Paper No. w11306.

Rey, H., 2015. Dilemma not trilemma: the global financial cycle and monetary policy independence. NBER Working Paper No. w2116.

Rogoff, K.S., Feldstein, M., 1999. Perspectives on exchange rate volatility. International Capital Flows, 441–453. Chicago: University of Chicago Press and NBER.

Stiglitz, J., 1999. Bleak growth prospects for the developing world. International Herald Tribune 10(6).

Tobin, J., 1974. The new economics one decade older. Princeton, NJ: Princeton University Press.

Wolfers, J., 2014. The Fed Has Not Stopped Trying to Stimulate the Economy. The New York Times. https://www.nytimes.com/2014/10/30/upshot/the-fed-has-not-stopped-trying-to-stimulate-the-economy.html?rref=upshot&abt=0002&abg=1

World Bank, 1985. World Bank Report. World Bank, Washington, DC.

Wu, J. C., Xia, F.D., 2016. Measuring the macroeconomic impact of monetary policy at the zero lower bound. Journal of Money, Credit, and Banking 48(2-3), 253-291.

Zeev, N.B., 2017. Capital controls as shock absorbers. Journal of International Economics 109, 43-67.

Zhang, X., 2003. Capital account management and its outlook in China. BIS Papers No. 15, Bank for International Settlements.

Appendix

Table A1: Variable definitions and data sources

Variable	Definition	Source
KC	Overall capital account restrictions index (all asset categories)	Chen and Qian (2016)
KCi	Overall inflow restrictions index (all asset categories)	Chen and Qian (2016)
KCo	Overall outflow restrictions index (all asset categories)	Chen and Qian (2016)
CID	Covered interest deviation, in %. CID = (r-r*)/(1+r*) - (F-S)/S, where (r-r*)/(1+r*) is the IRD and (F-S)/S is the expected rate of appreciation or FP. The variables r and r* are the Chibor and US dollar (USD) Libor rate, respectively; S is the spot rate quoted as units of RMB per USD; and F is the RMB non-deliverable forward (NDF) rate.	Bloomberg, DataStream, and authors' calculation
CID volatility	The variance of CID calculated with daily data	Bloomberg, DataStream, and authors' calculation
IRD	Interest rate differential, in %	Bloomberg, DataStream, and authors' calculation
IRD volatility	The variance of IRD calculated with daily data	Bloomberg, DataStream, and authors' calculation
FP	Forward premium, in %	Bloomberg, DataStream, and authors' calculation
FP volatility	The variance of FP calculated with daily data	Bloomberg, DataStream, and authors' calculation
GDP	China's nominal GDP in current price (million RMB); Monthly data are interpolated monthly industrial production data, in log.	China National Bureau of Statistics (NBS)
Openness	China's trade openness, total trade as a percentage of GDP	IFS
NDF spread	RMB foreign exchange market liquidity, NDF bid–ask spread for 3-month maturity, monthly average, in log	Bloomberg
NEER	The RMB nominal effective exchange rate, 2010 = 100	BIS
VIX	Chicago Board Options Exchange, CBOE Volatility Index	CBOE
Exchange rate volatility	Exchange rate volatility, standard deviation of daily data, in log	Bloomberg
GFC	Global financial crisis, GFC = 1 between December 2007 and June 2009; otherwise, 0.	NBER
QE	US monetary quantitative easing, QE = 1 after February 2009 when the American Recovery and Reinvestment Act of 2009 was signed into law	

Reform2005	China exchange rate regime reform, Reform05 = 0 before July 2005 and = 1 thereafter
Reform2015	China exchange rate reform, Reform15 equals 0 before August 2015 and = 1 thereafter
RMB exch liber	Order dummy variable measuring RMB exchange regime liberalization (see Table A2 for details)

Table A2: RMB exchange rate regime liberalization

0	Before 7/2005	Daily trading band for the USD/CNY rate at ±0.3%
1	7/2005-5/2007	Exchange rate reform
2	5/2007-4/2012	Daily trading band for the USD/CNY rate at ±0.5%
3	4/2012-3/2014	Daily trading band for the USD/CNY rate at ±1%
4	3/2014-8/2015	Daily trading band for the USD/CNY rate at ±2%
5	8/2015-9/2015	Improved the mechanism of USD/CNY central parity rate formation: the daily central parity quotes reported to the China Foreign Exchange Trade System (CFETS) before the market opens should be mainly based on the closing rate of the inter-bank foreign exchange market on the previous day, and make minor adjustment according to the price movements of major currencies, foreign exchange supply and demand on the previous day.
6	9/2015-1/2016	Allowed foreign central banking institutions to participate in the onshore interbank FX market.
7	1/2016-8/2017	The daily trading time of the Chinese interbank FX market was extended to 23:30 Beijing time. Qualified overseas participating banks with RMB purchases and sales business could apply to CFETS for the Chinese interbank FX market membership and conduct trading of all traded FX products through CFETS trading system.

Note: Sources of these policies are “RMB Internationalization Report (2015-2017)” from PBOC and “中国货币政策大事记”(2010-2017).

Table 1: Descriptive statistics of variables (January 1999–December 2016)

Variable	Obs.	Mean	Std. Dev.	Min.	Max.	I(1) test
KC	216	-1.275	1.033	-3.861	0.310	-3.143***
KCi	216	-1.239	1.203	-5.000	0.000	-2.347**
KCo	216	-1.733	1.240	-3.583	0.583	-4.278***
CID	221	0.516	0.966	-2.298	3.498	-3.200***
IRD	221	0.445	0.632	-1.038	2.212	-1.788
FP	223	-0.051	0.967	-2.831	2.615	-1.864
CID Volatility	213	0.082	0.158	0.000	1.851	-4.288***
IRD Volatility	213	0.031	0.048	0.000	0.340	-4.164***
FP Volatility	213	0.050	0.150	0.000	1.843	-2.416**
Openness	218	0.254	0.146	0.084	0.711	-1.393
GDP	218	15.371	0.915	13.366	17.029	-0.296
NDF spread	223	0.021	0.137	0.000	1.462	-0.654
VIX	223	20.329	7.972	10.260	59.890	-3.451***
NEER	218	100.271	11.456	83.820	127.410	-1.711
Exch Rate Volatility	221	0.009	0.012	0.000	0.086	-2.290**
Descriptive Statistics for 3-month-CIDs of four different currencies (March1999-July2017)						
JPY	221	0.036	0.038	-0.049	0.206	
CAD	221	0.042	0.069	-0.052	0.238	
KRW	221	0.127	0.270	-0.773	1.492	
RMB	221	0.516	0.966	-2.298	3.498	

Note: I(1) test uses DF-GLS unit root test with Elliott, Rothenberg, and Stock (1996) critical values. All tests include a constant and time trend, except volatility variables for which the time trend is dropped.

Table 2: Capital controls and the volatility of the RMB covered interest deviation (CID)

	(1)	(2)	(3)	(4)
CID volatility (-1)	0.018	-0.176**	-0.194***	-0.157**
	(0.249)	(-2.406)	(-2.703)	(-2.400)
CID_volatility (-2)		-0.215***	-0.218***	-0.147**
		(-2.983)	(-3.093)	(-2.305)
CID_volatility (-3)		-0.194**	-0.188**	
		(-2.563)	(-2.495)	
ΔNDF spread	0.063***	0.037*	0.046**	
	(2.686)	(1.690)	(2.161)	
Exchange rate volatility	0.021**	0.024***	0.025***	0.021***
	(2.524)	(3.098)	(3.341)	(3.002)
ΔNEER			-0.020**	-0.027***
			(-2.056)	(-2.831)
VIX				0.007***
				(4.777)
GFC		0.155***	0.102**	
		(3.195)	(2.142)	
QE	-0.110*	-0.173*	-0.350***	-0.323***
	(-1.776)	(-1.672)	(-3.883)	(-2.884)
Reform2015	0.233***	3.698***	2.892***	8.340***
	(3.069)	(6.544)	(6.292)	(7.843)
KC	0.133**	0.130*		
	(2.208)	(1.675)		
QE × KC		-0.118**		
		(-2.537)		
Reform2015 × KC		0.980***		
		(6.200)		
KCi			0.317***	
			(4.661)	
QE × KCi			-0.293***	
			(-5.092)	
Reform2015 × KCi			0.604***	
			(5.962)	
KCo				-0.061
				(-1.341)
QE × KCo				-0.132***
				(-2.710)
Reform2015 × KCo				2.369***
				(7.781)
Observations	179	179	179	183
Adjusted R^2	0.128	0.280	0.323	0.348

Note: The dependent variable is the variance of the CID. Column (1) reports results of equation (1). Columns (2) – (4) report equation (2) results with capital controls being overall controls, controls on inflows, and controls on outflows, respectively. *Δ* is the first-difference operator; the trend and constant are not reported; t statistics based on robust errors are in parentheses. ***, **, and * are significance levels at 1, 5, and 10%, respectively.

Table 3: Capital controls and the volatility of the RMB–USD interest rate differential (IRD)

	(1)	(2)	(3)
IRD volatility (-1)	0.355***	0.320***	0.356***
	(4.745)	(4.390)	(4.862)
ΔGDP	0.033**	0.033**	0.033**
	(2.255)	(2.244)	(2.223)
ΔOpenness	0.111**	0.113**	0.109**
	(2.106)	(2.168)	(2.042)
Reform2005	0.027*		0.025*
	(1.750)		(1.673)
QE	-0.044	-0.040*	-0.043
	(-1.513)	(-1.836)	(-1.462)
KC	0.042**		
	(2.079)		
QE × KC	-0.042***		
	(-2.893)		
KCi		0.057***	
		(3.348)	
QE × KCi		-0.054***	
		(-3.558)	
KCo			0.009
			(0.695)
QE × KCo			-0.030**
			(-2.150)
Observations	183	191	191
Adjusted R^2	0.354	0.343	0.315

Note: The dependent variable is the variance of the IRD; Columns (1) – (3) report equation (3) results with capital controls being overall controls, controls on inflows, and controls on outflows, respectively. The trend and constant are not reported; t statistics based on robust errors are in parentheses; ***, **, and * are significance levels at 1, 5, and 10%, respectively.

Table 4: Capital controls and the volatility of the RMB forward premium (FP)

	(1)	(2)	(3)
FP volatility (-1)	-0.227***	-0.221***	-0.183***
	(-3.339)	(-3.100)	(-2.849)
FP volatility (-2)	-0.289***	-0.281***	-0.214***
	(-4.324)	(-4.007)	(-3.395)
FP volatility (-3)	-0.283***	-0.282***	
	(-4.248)	(-3.982)	
ΔNDF spread	0.057***	0.050***	0.039**
	(3.553)	(3.092)	(2.431)
Exch rate volatility	0.031***		
	(3.027)		
ΔNEER			-0.025***
			(-2.971)
VIX			0.006***
			(4.831)
GFC	0.163***	0.181***	
	(4.237)	(4.726)	
Reform2005	-0.053		
	(-0.867)		
QE			-0.106**
			(-2.045)
Reform2015	4.030***	3.262***	8.201***
	(8.124)	(7.487)	(8.281)
KC	-0.075		
	(-1.419)		
Reform2005 × KC	0.113**		
	(2.178)		
Reform2015 × KC	1.059***		
	(7.717)		
KCi		0.016	
		(0.661)	
Reform2015 × KCi		0.670***	
		(7.015)	
KCo			-0.044
			(-1.070)
Reform2015 × KCo			2.318***
			(8.218)
Observations	181	181	181
Adjusted R^2	0.371	0.305	0.386

Note: The dependent variable is the variance of FP. Columns (1) – (3) report equation (4) results with capital controls being overall controls, controls on inflows, and controls on outflows, respectively. *Δ* is the first-difference operator; the trend and constant are not reported; t statistics based on robust errors are in parentheses. ***, **, and * are significance levels at 1, 5, and 10%, respectively.

Table 5: Capital controls and the volatility of RMB CID—an error correct model (ECM) result

	(1)	(2)	(3)
Error correction (α)	-0.915***	-0.968***	-0.994***
	(-12.961)	(-13.486)	(-14.288)
KC_{t-1} (β)	0.033**	0.047***	0.035**
	(2.085)	(2.948)	(2.054)
ΔNDF spread	0.036*	0.037*	0.034*
	(1.837)	(1.881)	(1.789)
ΔNEER	-0.018*		
	(-1.803)		
Exchange rate volatility	0.020***		0.024***
	(2.810)		(3.140)
GFC			-0.036
			(-1.099)
Reform 2015		0.244***	0.118***
		(3.529)	(2.721)
Δ KC	0.030**		
	(2.099)		
Δ KCi		0.045***	
		(2.898)	
Δ KCo			0.035**
			(2.047)
GFC × Δ KCo			1.779***
			(3.426)
Bound test, F	85.25	91.02	102.28
Bound test, t	-12.96	-13.48	-14.28
Observations	187	187	187
Adjusted R^2	0.480	0.489	0.523

Note: The dependent variable is the first-differenced variance of the CID. Columns (1) – (3) report equation (5) results with capital controls being overall controls, controls on inflows, and controls on outflows, respectively. KC_{t-1} takes one-period lagged values of KC, KCi, and KCo in these three regressions. *Δ* is the first-difference operator; the constant is not reported; t statistics based on robust errors are in parentheses. ***, **, and * are significance levels at 1, 5, and 10%, respectively. ECM is specified in Equation (5); bound tests confirm the long-run relationship.

Table 6: Capital controls and the volatility of IRD—an error correction model (ECM) result

	(1)	(2)	(3)
Error correction (α)	-0.592***	-0.612***	-0.617***
	(-8.676)	(-8.839)	(-8.895)
KC_{t-1} (β)	0.018***	0.010**	0.017***
	(3.724)	(2.072)	(4.272)
ΔNDF spread	-0.011**	-0.011**	-0.010**
	(-2.031)	(-2.067)	(-1.986)
Exchange rate volatility		0.005*	
		(1.897)	
Reform 2005		-0.035***	
		(-2.669)	
Δ KC	0.011***		
	(3.411)		
Δ KCi		0.006**	
		(2.034)	
Δ KCo			0.011***
			(3.819)
Bound test, F	37.64	39.11	39.57
Bound test, t	-8.67	-8.83	-8.89
Observations	187	187	187
Adjusted R^2	0.287	0.290	0.297

Note: The dependent variable is first-differenced variance of the IRD. Columns (1) – (3) report equation (5) results with capital controls being overall controls, controls on inflows, and controls on outflows, respectively. KC_{t-1} takes one-period lagged values of KC, KCi, and KCo in these three regressions. *Δ* is the first-difference operator; the constant is not reported; t statistics based on robust errors are in parentheses. ***, **, and * are significance levels at 1, 5, and 10%, respectively. ECM is specified in Equation (5); bound tests confirm the long-run relationship.

Table 7: Capital controls and the volatility of FP—an error correction model (ECM) result

	(1)	(2)	(3)
Error correction (α)	-0.990***	-0.984***	-0.958***
	(-14.275)	(-14.189)	(-16.432)
KC_{t-1} (β)	-0.005	0.024	-0.021
	(-0.231)	(1.369)	(-1.455)
ΔNDF spread	0.047***	0.047***	0.030**
	(2.633)	(2.668)	(2.057)
ΔNEER	-0.021**	-0.018*	-0.024***
	(-2.236)	(-1.896)	(-3.055)
Exchange rate volatility	0.017**	0.016***	0.012**
	(2.573)	(2.760)	(2.009)
VIX	0.005***	0.004***	0.005***
	(3.400)	(2.771)	(4.293)
QE	-0.054*		-0.069***
	(-1.733)		(-2.648)
Reform2015	0.097*	0.163**	0.078**
	(1.762)	(2.426)	(2.250)
Δ KC	-0.005		
	(-0.231)		
Δ KCi		0.024	
		(1.368)	
Δ KCo			-0.020
			(-1.443)
Reform2015 × Δ KCo			2.625***
			(9.107)
Bound test, F	102.18	100.082	135.43
Bound test, t	-14.27	-14.18	-16.43
Observations	187	187	187
Adjusted R^2	0.532	0.529	0.677

Note: The dependent variable is the first-differenced variance of FP. Columns (1) – (3) report equation (5) results with capital controls being overall controls, controls on inflows, and controls on outflows, respectively. KC_{t-1} takes one-period lagged values of KC, KCi, and KCo in these three regressions. *Δ* is the first-difference operator; the constant is not reported; t statistics based on robust errors are in parentheses. ***, **, and * are significance levels at 1, 5, and 10%, respectively. ECM is specified in Equation (5); bound tests confirm the long-run relationship.

Table 8: Capital controls and the volatility of RMB CID—alternative exchange rate regime

	(1)	(2)	(3)
CID volatility (-1)	-0.044	-0.060	-0.041
	(-0.591)	(-0.820)	(-0.549)
ΔNDF spread	0.059**	0.059***	0.064***
	(2.586)	(2.637)	(2.731)
ΔNEER	-0.036***	-0.037***	-0.034***
	(-3.365)	(-3.600)	(-3.085)
Exchange rate volatility	0.024**	0.030***	
	(2.445)	(3.146)	
VIX	0.007***	0.007***	0.008***
	(4.167)	(3.831)	(4.264)
QE	-0.427***	-0.318***	-0.880***
	(-3.926)	(-4.260)	(-3.843)
RMB exch libr	0.022	-0.007	0.212***
	(0.463)	(-0.203)	(2.868)
KC	0.030		
	(0.694)		
RMB exch libr × KC	0.023*		
	(1.938)		
QE × KC	-0.247***		
	(-3.643)		
KCi		0.113*	
		(1.941)	
RMB exch libr × KCi		0.015**	
		(2.269)	
QE × KCi		-0.267***	
		(-4.112)	
KCo			0.025
			(0.960)
RMB exch libr × KCo			0.066***
			(3.056)
QE × KCo			-0.322***
			(-3.500)
Observations	170	170	170
Adjusted R^2	0.197	0.230	0.164

Note: The dependent variable is the variance of the CID. RMB exch libr is used to measure the RMB exchange rate regime. Columns (1) – (3) report equation (2) results with capital controls being overall controls, controls on inflows, and controls on outflows, respectively. The trend and constant are not reported; t statistics based on robust errors are in parentheses; ***, **, and * are significance levels at 1, 5, and 10%, respectively.

Table 9: De facto capital controls (proxied by absolute value of CID) and the volatility of RMB CID

	(1)	(2)
CID_volatility (-1)	0.041	0.014
	(0.578)	(0.197)
Absolute CID	0.029*	0.028
	(1.722)	(1.586)
ΔNDF spread	0.059***	0.046**
	(2.680)	(2.182)
ΔNEER	-0.019**	-0.016
	(-2.016)	(-1.632)
Exchange rate volatility	0.019**	0.019***
	(2.580)	(2.664)
VIX	0.004***	0.004***
	(2.879)	(3.071)
Reform2015		0.008
		(0.143)
Reform2015 × Absolute CID		0.241***
		(3.636)
Observations	187	187
Adjusted R^2	0.131	0.220

Note: The dependent variable is the variance of the CID. Absolute CID is used to measure capital controls. Column (1) reports equation (1) results and column (2) reports equation (2) results. The trend and constant are not reported; t statistics based on robust errors are in parentheses; ***, **, and * are significance levels at 1, 5, and 10%, respectively.

Table 10: Capital controls and the volatility of RMB CID using CHN forward rate

	(1)	(2)	(3)
CID volatility (-1)	-0.086	-0.079	-0.063
	(-1.091)	(-0.962)	(-0.804)
CID volatility (-2)	-0.202***	-0.205***	-0.174**
	(-2.860)	(-2.761)	(-2.535)
VIX	0.011***	0.010***	0.010***
	(4.244)	(3.841)	(4.144)
Reform2015	0.608***	0.601***	1.526***
	(2.788)	(3.306)	(3.546)
KC	0.112*		
	(1.854)		
Reform2015 × KC	0.141**		
	(2.250)		
KCi		0.032	
		(0.795)	
Reform2015 × KCi		0.114***	
		(2.690)	
KCo			0.089*
			(1.872)
Reform2015 × KCo			0.421***
			(3.451)
Observations	63	63	63
Adjusted R^2	0.508	0.467	0.519

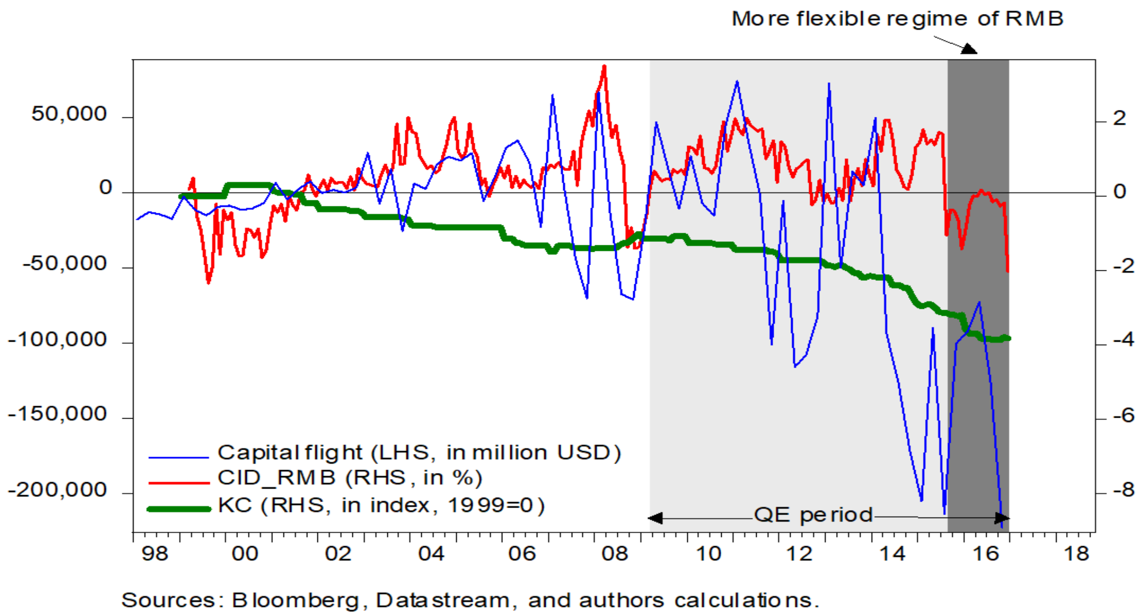
Note: The dependent variable is the variance of the CID. CID is calculated by using CHN forward rate. Columns (1) – (3) report equation (2) results with capital controls being overall controls, controls on inflows, and controls on outflows, respectively. The trend and constant are not reported; t statistics based on robust errors are in parentheses; ***, **, and * are significance levels at 1, 5, and 10%, respectively.

Table 11: Capital controls and the conditional volatility of RMB CID

	(1)	(2)	(3)
CID volatility (-1)	0.209***	0.180***	0.342***
	(3.125)	(2.694)	(5.374)
VIX	0.005***	0.005***	0.006***
	(3.347)	(3.420)	(3.841)
QE	-0.431***	-0.395***	-0.169
	(-3.900)	(-4.925)	(-1.400)
Reform2015	2.639***	2.468***	4.181***
	(5.225)	(5.836)	(3.567)
KC	0.249***		
	(2.949)		
QE × KC	-0.098**		
	(-2.139)		
Reform2015 × KC	0.693***		
	(4.875)		
KCi		0.234***	
		(3.712)	
QE × KCi		-0.198***	
		(-3.513)	
Reform2015×KCi		0.523***	
		(5.560)	
KCo			0.013
			(0.225)
QE × KCo			-0.011
			(-0.189)
Reform2015 × KCo			1.186***
			(3.530)
Observations	201	201	201
Adjusted R^2	0.404	0.420	0.338

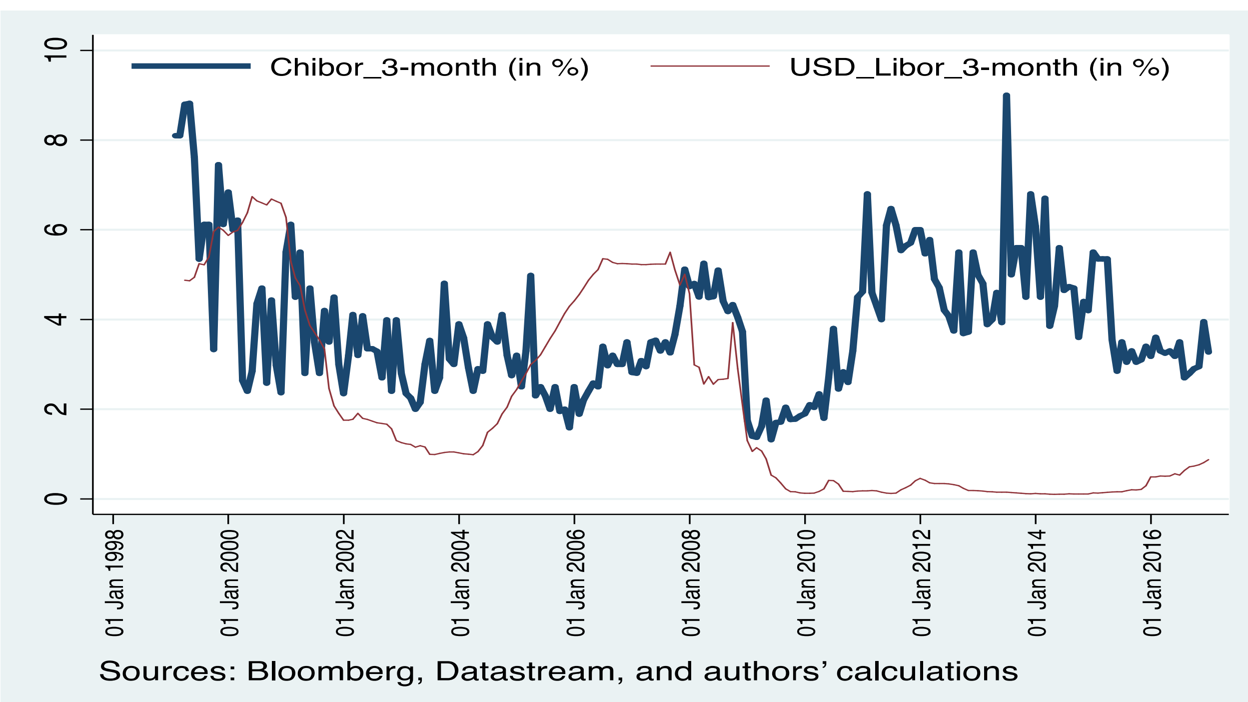
Note: The dependent variable is the conditional volatility of CID based on GARCH (1,1) model. Columns (1) – (3) report equation (2) results with capital controls being overall controls, controls on inflows, and controls on outflows, respectively. The trend and constant are not reported; t statistics based on robust errors are in parentheses; ***, **, and * are significance levels at 1, 5, and 10%, respectively.

Figure 1: RMB CID, China's capital controls index, and capital flight



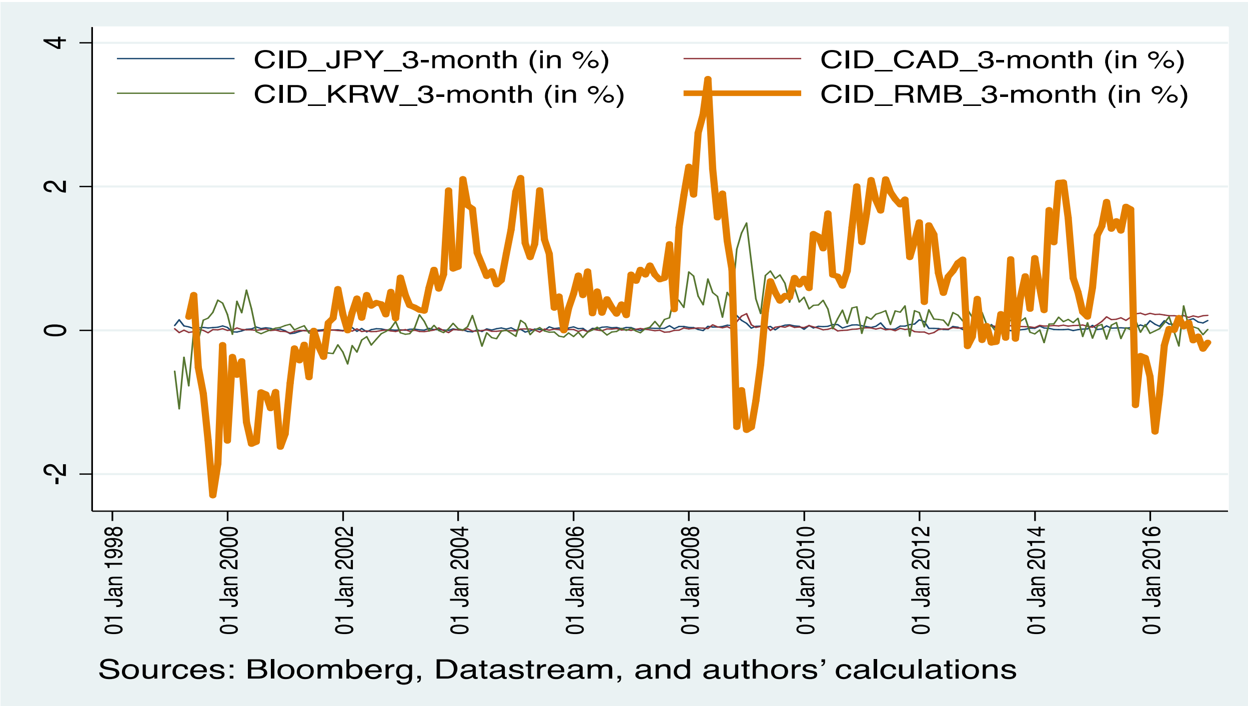
Notes: China's capital flight is calculated according to World Bank's residual method. The calculation details are from Cheung and Qian (2010).

Figure 2: The relation between RMB and USD interest rate



Note: the figure plots the relation between RMB Chibor rate and USD Libor rate and their seemingly divergence after the 2008 global financial crisis.

Figure 3: The comparison of four CIDs: Japanese yen (JPY), Canadian dollar (CAD), Korean won (KWD), and Chinese renminbi (RMB)



Note: JPY and CAD are free of capital controls; KWD and RMB are subject to cross-border capital controls.