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Interactions between CNY and CNH Money and Forward Exchange Markets*

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Abstract

We analysed the interactions between the RMB deliverable forward markets in Mainland China and Hong Kong. In order to broaden our perspective, we reference this to the Eurodollar market from the late 1950s to early 1980s. Our findings suggest that onshore regulations, notably the Regulation Q interest rate ceiling, were effective in containing spillovers between the Eurodollar market and the US domestic market. For the CNH market, we found evidence that cross-market spillovers between the Mainland and CNH markets became two-way in 2013, but were more limited and mostly not significant in earlier years. It was found that onshore-to-offshore spillovers were larger than spillovers in the opposite direction in most cases. This probably reflects the fact that the CNH market, though rapidly growing, is small compared to the Mainland market, and possibly more subject to onshore influences. Looking ahead, the Mainland market is expected to continue to play a leading role in onshore-offshore money and foreign exchange market interactions since these markets will be ultimately dominated by the monetary policy stance of the onshore authorities.

Keywords: Eurodollar, Renminbi, Deliverable Forward Market, Offshore Markets, Regulation Q, Capital Control, Multivariate GARCH, Price Discovery

JEL Classification: F30, G1, G12, G15

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1. Introduction

Hong Kong's renminbi (RMB) offshore market, also widely known as the CNH market, has developed rapidly since 2010, following a series of landmark policies that laid its foundation[1]. First, the Hong Kong Monetary Authority issued a circular on 11 February 2010 to elucidate the supervisory principles and operational arrangements of the RMB business in Hong Kong[2]. Second, the People's Bank of China and the RMB Clearing Banking in Hong Kong signed a revised Clearing Agreement on 19 July 2010, which significantly reduced the restrictions faced by banks in establishing RMB accounts for, and providing related services to, financial institutions. Third, a pilot RMB trade settlement scheme was expanded on 22 June 2010 to cover 20 provinces and cities on the Mainland, allowing their trade transactions with any part of the world to be settled in RMB, thus bolstering the pool of RMB liquidity outside Mainland China.

Following these measures, the CNH market has grown rapidly since 2010, with RMB deposits surging to RMB 945 billion by the end of March 2014, compared to RMB 315 billion at the end of 2010. Meanwhile RMB trade settlements rose to RMB 602.4 billion in March 2014 from RMB 10.3 billion in July 2010[3]. RMB financial products, such as bonds (dim sum bonds), bank lending, certificates of deposits and various related derivative products, have also proliferated. In particular, dim sum bonds issued in the CNH market totalled RMB116.6 billion in 2013, a 2.3 times increase from the RMB35.8 billion in 2010[4].

As the CNH market has taken off, its interaction with the Mainland onshore market, also known as the CNY market, has drawn increasing attention due to the potential implications for financial stability and the risk management of banks located in the two markets. Earlier studies tend to focus on the RMB spot foreign exchange market, which was one of the earliest developed segments in the CNH market[5]. However, as the CNH market becomes more mature, it is also crucial to assess the onshore-offshore interactions of other market segments. A better understanding of these interactions could also shed light on the functioning of this offshore market, notably its role in price discovery, i.e. efficiency in incorporating new information about fundamentals into the market price[6]. Against this backdrop, this paper investigates the interactions of RMB deliverable forward (DF) contracts traded in the two

1 For details of these policies, see Box 3 in the HKMA Half Yearly Monetary and Financial Stability Report, September 2010, at www.hkma.gov.hk.

2 Under these guidelines, banks and other financial institutions are able to offer a wide range of RMB businesses in Hong Kong that do not involve the flow of RMB funds back to the Mainland.

3 The pilot scheme of RMB trade settlement was introduced in July 2009, but the first RMB trade settlement data was available since July 2010.

4 For more details about the recent development of the CNH market, see Chan (2014).

5 For example, see Maziad and Kang (2012).

6 Lehmann (2002) defined 'price discovery' as the processing of information which passes through trade into market prices. When trading related instruments in two markets, the contributions to price discovery can be divided into these two markets.

markets, with a focus on two issues: (1) cross-market spillovers, i.e. the impact of stochastic shocks in one market on the volatility in another market; and (2) the functioning of the two markets in the process of price discovery.

Given the short history of the CNH market, econometric analysis is inevitably confined to relatively short data series. Therefore, to broaden our perspective, we also examine the historical experiences of the Eurodollar market, which is the most important and sophisticated offshore market of the world, with its origin dating back to the late 1950s. Admittedly, the historical context, regulatory regimes and money market conditions of the Eurodollar market differ from the CNH market but there are aspects that make the historical case relevant to China. In particular, in the 1970s and early 1980s, the US relaxed and finally eliminated its Regulation Q interest rate ceiling and other capital control measures. While the Mainland market is also subject to regulations on interest rates and capital flows, the Chinese authorities have announced that such restrictions will be liberalised in coming years[7]. Therefore, bearing in mind the obvious differences between the two cases, the experiences of the Eurodollar market can still give us food of thought in understanding CNH market development as well as its interaction with the Mainland market.

The remainder of this paper is organised as follows. In Section 2, we set the stage for a broader discussion by tracing the key regulatory changes and developments related to the Eurodollar market. We draw comparisons between the Eurodollar market and the CNH market. Section 3 presents an empirical study on the Eurodollar market and discusses the econometric models used for the analysis of the historical data, which consist of money market rates for the Eurodollar and US domestic markets of 1964-1995. In order to assess cross-market dynamics, the models we use are vector autoregression (VAR) model and bivariate generalised autoregressive conditional heteroscedasticity (GARCH) model. The major findings are presented in this section. In Section 4, we turn our attention to the Mainland and CNH market, using essentially the same models to conduct quantitative analysis. We discuss the data sources and the main findings. Section 5 offers concluding remarks.

2. Regulations and Development of the Eurodollar Market

Broadly speaking, the Eurodollar is US dollar denominated short-term deposits in banks or bank branches outside the United States. London was where the Eurodollar market began to develop in the 1950s and – despite the rapid growth in Japan, Hong Kong, Singapore and some Caribbean countries subsequently – remains the largest offshore centre, accounting for approximately 20% of total offshore dollar deposits at the end of 2013.[8] Figure 1 shows that the Eurodollar market has sustained

[7] For example, the People's Bank of China (PBoC) expected deposit rate liberalization to be achieved in one or two years. For details, see PBoC Press Release dated 11 March 2014. PBoC also released a report on 23 February 2012 envisaging that the capital account liberalization process would be completed in a 10-year horizon.

[8] As the data on the US dollar deposits of individual countries are classified as "restricted" by the data source, the Bank for International Settlements (BIS), we use figures of all foreign currency deposits placed by foreign entities in individual countries as a reference. These data reflect to a large extent the pattern of offshore US dollar deposits, since the latter has been the dominant deposit in all offshore foreign currency deposits, accounting for more than half (56.5%) of the total at the end of 2013.

robust growth since its birth[9]. Prior to the global financial crisis in 2008-09, its size was equivalent to approximately 30% of the total deposits in the US domestic market.

The phenomenal growth of the Eurodollar market is attributable to a wide range of politico-economic factors.[10] This study focuses on one of these factors, namely, US banking policies and regulations. In a number of episodes, the growth of the Eurodollar market was an unintended consequence of the introduction of some policy measures that created opportunities for regulatory arbitrage. On the one hand, a more restrictive domestic environment encouraged some banking activities to relocate themselves offshore to avoid those regulations. On the other, developments in the offshore market also influenced the formulation of the regulations onshore. This section highlights the interaction between US regulations and the growth of the Eurodollar market. A chronology of the major policies and economic events affecting Eurodollar market development is given in the Appendix.

2.1 Regulation Q Interest Rate Ceilings (1933-1986)

Among all the US banking policies and regulations, Regulation Q was probably the most directly related to the growth of the Eurodollar market. (Dufey and Giddy (1994), Friedman (1969)) The regulation, which was part of the 1933 and 1935 Banking Acts, prohibited the payment of interest on demand deposits and authorized the Federal Reserve to impose ceilings on savings and time deposits interest rates in US commercial banks. Its primary objective was to encourage smaller banks to lend in their local communities rather than hold balances with larger banks in other major financial centres. Another intention was to reduce competition for customers' deposits, which was regarded as a main factor that caused banks to acquire riskier assets thereby threatening the stability of the banking system.

Prior to the late 1960s, the ceiling rates were generally higher than free market rates, thus having little impact on US banks. However, following accelerating inflation in the 1970s, the ceiling rates fell below free market rates. The deposit rates offered by the lightly regulated offshore market in London and other major money centres were therefore more attractive to depositors. As a consequence, there were large withdrawals of deposits from US banks, which were re-deposited in offshore banks, causing US banks to experience a shortage of funds. Borrowing from foreign branches of US banks by their head offices therefore increased, driving the growth of the offshore market. In addition to Regulation Q, the absence of other regulatory burdens (e.g. reserve requirement, insurance costs imposed by the Federal Deposit Insurance Corporation) also implied competitive advantages to

[9] As the Federal Reserve series only covers US dollar deposits held in foreign financial institutions by private US owners, it serve only as a proxy indicator for the Eurodollar market. BIS data have a broader coverage, but consistently defined and regular data are only available after 1977.

[10] Other factors crucial to the Eurodollar market development include the US balance of payments deficits, the reluctance of the Soviet Union to deposits its US dollar earnings from crude oil exports in the US domestic banking system during the Cold War, the gradual relaxation of exchange-rate controls in Europe and the breakdown of the Bretton Woods fixed exchange rate system. For more discussion of these factors, see Levich (2002), Dufey and Giddy (1994) and Schenk (1998).

offshore banks over US banks. As a result, offshore banks were able to conduct their businesses on a narrower net interest margin than domestic banks.

Another development is that Regulation Q was amended in 1966 with an extension to thrift institutions[11] in order to limit the increase in residential mortgage interest rates and to promote a stable supply of mortgage credit. Ceilings were set slightly higher at thrift institutions than at commercial banks to induce depositors at banks to shift their deposit accounts to thrifts, thus increasing the amount of mortgage credit available to homebuyers with lower mortgage interest rates.

In 1980, the US Congress concluded that interest rate ceilings were unable to accomplish the desired results, namely, increasing the supply of mortgage credit and containing the competition for deposits. Subsequently, it passed the Monetary Control Act which established a procedure to phase out Regulation Q over a six-year period, with complete abolition in 1986.

2.2 Measures to Discourage Capital Outflow (1963-1974)

The experience of the Eurodollar market suggests that policies by the onshore authorities to restrict capital outflows might have had the unintended consequence of boosting the offshore market. In July 1963, the US authorities introduced the Interest Equalisation Tax (IET) to discourage investing abroad, by taxing the interest on foreign securities, in an attempt to deal with the worsening balance of payments. By raising the price of long-term borrowing, the US encouraged foreigners to go elsewhere for borrowed funds, such as the Eurodollar market and the Eurobond market.

As it became clear that the IET was ineffective in stopping capital outflows, the Federal Reserve launched the Foreign Credit Restraint Program that imposed specific limits on the volume of foreign lending by US banks, including loans to foreigners and investment in other foreign assets. When the program was introduced in 1965, it was implemented on a voluntary basis but was subsequently made mandatory in 1968. As the program applied only to businesses located in the US, it resulted in a shift of operations to foreign branches of US firms and in particular to the Eurodollar market. Foreign branches of US banks, which were not subject to the program, took deposits and lent them outside the ceiling.

As a result of these measures to restrict capital outflows, foreign corporations found it more costly to borrow in the US market. In order to circumvent the capital control measures, foreign borrowers turned to the Eurodollar market. They were able to raise US dollar funding in the Eurodollar market since Regulation Q interest rate ceiling had encouraged relocation of US dollar deposits to the Eurodollar market. Therefore, capital control measures and interest rate regulations were likely complementary in spurring the growth of the offshore market.

[11] Thrift institutions include savings and loan associations, savings banks and credit unions.

In January 1974, the program was officially abolished, although controls were partially relaxed in late 1973. US banks could freely arbitrage between the US domestic market and the Eurodollar market. This led to greater integration between the onshore and offshore segments of the dollar market.

2.3 Reserve Requirement on Eurodollar Borrowings (1969-1980)

Prior to 1969, US banks were not subject to reserve requirements on Eurodollar borrowings, and were able to benefit from a clearing process bonus in their excess reserves when borrowing Eurodollars. In order to control domestic credit expansion that depended on Eurodollar funding, US regulators amended Regulations D and M[12] in October 1969. The new measures imposed a 10% reserve requirement on Eurodollar borrowings above a specified base by US banks from their foreign branches. In January 1971, the reserve requirement ratio was raised to 20%. These measures were effective in discouraging US banks from circumventing the Federal Reserve monetary control. As shown in Figure 2, throughout most of the mid-1970's, US banks maintained a net lending position against their offshore banks, reversing their net borrowing position in the 1960's.

Nonetheless, the above regulations created competitive disadvantages to US chartered banks versus foreign-chartered banks. This is because the Eurodollar reserve requirements were based not only on US banks' net borrowing from the Eurodollar market but also their lending to US non-bank customers booked at their foreign branches. This required the collection of detailed data on the foreign branches of US banks. Foreign banks operating in the US need not provide such detailed information on their offshore operations and therefore were in a better position to benefit from regulatory arbitrages. Subsequently, the government lowered the reserve requirements on Eurodollar borrowings from 20% to 8% in June 1973 and then to 4% in May 1975. Regulations D and M were further amended to remove such requirements in August 1978 with a view to encouraging US banks to borrow in the Eurodollar market so that they could compete on an equal basis with foreign chartered banks.

In early 1979, Eurodollar markets were flooded with new deposits following the second oil shock and downward pressure of Eurodollar rates. US banks quickly reversed their net position with their own foreign offices, from being net suppliers to net takers (Figure 2). In October 1979, the Federal Reserve imposed marginal reserve requirements on managed liabilities (including both Eurodollar borrowings and large certificates of deposits) and introduced the new monetary policy operating procedures that placed greater emphasis on reserve movements and less emphasis on federal funds rate fluctuations. These changes were intended to reduce the inflationary momentum and enhance the implementation of monetary policy.

In March 1980, as US banks reduced their net position with their own foreign branches to nearly zero, the Federal Reserve implemented the credit restraint program and increased marginal reserve requirements to reduce the ability of US banks to expand domestic credit. As a result, foreign

[12] Regulations D and M are Federal Reserve Board regulations governing the reserve requirements of depository institutions.

borrowers re-entered the Eurodollar market. US banks transferred funds offshore due to strong external credit demands and reversed once again their net position with their offshore branches.

2.4 International Banking Facilities (1981-Present)

While US banks were active in the offshore markets, US policymakers turned their attention to the concern over attracting offshore banking activities within their regulatory jurisdictions. In December 1981, the Federal Reserve introduced international banking facilities (IBFs) which establish a "separate set of books" within an existing banking institution. Such IBFs are exempt from deposit reserve requirements, interest rate ceilings and federal deposit insurance. Since then, the IBF legislation has created an offshore banking environment located physically within the US, making IBFs fully competitive with true offshore banking operations. However, the IBFs were unable to challenge the Eurodollar market, which was already well established by the early 1980s. As at September 2010, the US dollar deposits placed in the IBFs were equivalent to only 6.4% of those in the Eurodollar market.

2.5 Comparing Eurodollar Market with CNH Market

In essence, two differences between the CNH and the Eurodollar market are noteworthy. The first concerns the key drivers of growth of these markets. The development of the CNH market has been primarily led by the relaxation of capital control measures by the Mainland authorities to allow market forces to play a more prominent role in market development. During this process, the restrictions on cross-border capital flows have been lifted, by a gradualist approach with a close working relationship between the monetary authorities of the Mainland and Hong Kong. By contrast, the robust growth of the Eurodollar market during its initial years was unplanned and largely the unintended consequences of market forces – notably by market participants actively taking advantage of the disparities between US domestic interest rates and the corresponding interest rates in the Eurodollar market. While the Mainland market is also subject to capital control and regulations in its money market and banking market[13], cross-market arbitrage is unlikely to be a major growth driver for the CNH market due to effective capital controls by the Mainland authorities[14].

Second, the two markets differ in terms of the users of offshore liquidity. For the CNH market, offshore RMB is primarily used for transactions with counterparties involving Mainland entities, notably cross-border trade settlement, RMB portfolio and foreign direct investment into the Mainland, as well as Mainland tourists' spending in Hong Kong. These transactions provide crucial channels through which RMB liquidity is injected into the CNH market or circulated back to the Mainland. While offshore RMB transactions could be conducted purely among non-Mainland entities, such transactions are less

[13] Like the Regulation Q, deposits offered by commercial banks in Mainland China are also subject to interest rate ceilings. For details, see the PBoC website www.pbc.gov.cn.

[14] See Cheung and Herrala (2014) and Ma and McCauley (2008) for discussion about the effectiveness of Mainland China's capital control measures.

common. By contrast, it is common for offshore US dollar liquidity to be used among non-US residents, reflecting the highly internationalised nature of the US dollar. In fact, the Eurodollar market accounted for 31% and 34% of the world total US dollar deposits and loans at the end of 2013 respectively[15]. Given the sizeable pools of dollar loans and deposits outside the US, it appears that non US residents are[16] more active in the Eurodollar market.

3. Empirical Study of Eurodollar and US Domestic Market

3.1 Econometric Models

This section discusses the quantitative methods we use to assess the spillover of a shock originating in one market on the volatility in another market. In this study, volatility is defined as the conditional variances of the endogenous variables given the available information set in the financial markets. Since the objective of this study is not volatility forecasting, volatility is not defined on an *ex ante* basis by means of option-implied volatilities.

The analysis is conducted in two steps. The first step is to compute the impulse-response functions (IRF) of the endogenous variables. The aim of this preliminary step is to visualise how one market reacts to an exogenous shock from its own as well as from another market. At this stage, no restriction is imposed on the parameters of the model. Since IRF can only give us a preview about market reactions to same-market and cross-market shocks, further analysis is needed to assess cross-market interactions. In the second step, we therefore use a more enriched GARCH model to explicitly model time-varying volatilities and therefore directly estimate the magnitudes of the volatility spillover impacts. Specifically, we apply a bivariate GARCH model[17], which is fairly standard in the financial-economics literature to estimate the pattern of cross-market spillover effects. Compared to a univariate GARCH model, a bivariate model has the advantage of taking into account the stylised fact that many financial variables share and react to the same information set or shocks. The model is specified as follows:

$$\begin{bmatrix} \Delta y_{on,t} \\ \Delta y_{off,t} \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix} \begin{bmatrix} \Delta y_{on,t-1} \\ \Delta y_{off,t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{on,t} \\ \varepsilon_{off,t} \end{bmatrix} \quad (1)$$

$$\boldsymbol{H_t} = \mathbf{C}'\mathbf{C} + \mathbf{A}'\boldsymbol{\varepsilon_{t-1}}\boldsymbol{\varepsilon_{t-1}}'\boldsymbol{A} + \boldsymbol{B}'\boldsymbol{H_{t-1}}\boldsymbol{B}$$

[15] Estimation based on (1) BIS data on US dollar (as foreign currency) loans and deposits position of reporting countries and (2) Federal Reserve data of the balance sheet of US commercial banks (H.8).

[16] Even during the early years of the Eurodollar market, the Eurodollar market played an important role in US dollar banking. For details, see He and McCauley (2012).

[17] For more details about the specification and properties of multivariate GARCH models, see Engle and Kroner (1995).

Where:

$\Delta y_{on,t}$ daily or weekly change[18] of an onshore variable at time t

$\Delta y_{off,t}$ daily or weekly change of an offshore variable at time t

$\varepsilon_{on,t}\ and\ \varepsilon_{off,t}$ residual terms for the onshore and offshore equations respectively

$$\boldsymbol{\varepsilon_t} \equiv \begin{bmatrix} \varepsilon_{on,t} \\ \varepsilon_{off,t} \end{bmatrix}\ and\ \ \boldsymbol{\varepsilon_t} \mid \mathrm{I}_{t-1} \sim N(0, \boldsymbol{H_t})$$

$$\boldsymbol{H_t} = \begin{bmatrix} {\sigma^2}_{on,t} & \sigma_{onoff,t} \\ \sigma_{onoff,t} & {\sigma^2}_{off,t} \end{bmatrix}, \mathbf{C} = \begin{bmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{bmatrix}, \boldsymbol{A} = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix}, \boldsymbol{B} = \begin{bmatrix} \beta_{11} & 0 \\ 0 & \beta_{22} \end{bmatrix}$$

$\mu_i, \gamma_{ij}, \alpha_{ij}, \beta_{ij}$, c_{ij} are model parameters for i=1,2

Under this model specification, cross-market spillovers can be interpreted as the effect of a change in the residual terms of the mean equation on the conditional variances of the two markets, which are represented by the diagonal elements of the time-varying matrix H_t. Magnitudes of such cross-market effects could be measured by some function of the off-diagonal elements in the coefficient matrix A. More specifically,

- $(\alpha_{21})^2$ measures the spillovers from an onshore to an offshore market
- $(\alpha_{12})^2$ measures the spillovers from an offshore to an onshore market

3.2 Data Source

The data set for the analysis of the Eurodollar and US domestic markets consists of their respective money market interest rates, which are available since 12 June 1964. For the US market, the interest rates of certificate of deposits (CD) issued by major US banks are used as a proxy for US domestic interest rates. The offshore Eurodollar rates are represented by Eurodollar deposit rates offered by banks mainly domiciled in the UK. As both rates reflect banking-sector credit risks, their risk profiles are likely to be more comparable than using Treasury yields that reflect sovereign credit risks. All the data are obtained from the Federal Reserve. The availability of the data for a long period of time and from the same source makes sub-period analyses feasible. Since some of the earlier data series are available only on a weekly basis, this study is conducted using weekly data.

[18] The daily or weekly changes of the endogenous and control variable were used instead of their levels because the level data are non-stationary.

As shown in Figure 3, the two interest rates move in close tandem. In particular, the two series almost overlapped with each other after the early 1980s, suggesting that the banking services of the onshore and offshore markets are close substitutes for each other and subject to common shocks. Table 1 shows descriptive statistics for these interest rates.

Since our focus is on how regulatory changes affect the magnitude of spillover effects, the interest rate data are sub-divided into four sub-periods that correspond to major turning points in Regulation Q, which is widely regarded as the most important regulation triggering phenomenal growth of the offshore Eurodollar market:

(1) 1964-1970: In this period, Regulation Q was already introduced but it had not yet posted a binding constraint on US commercial banks, as interest rate ceilings were generally higher than the rates determined by free markets,

(2) 1971-1979: As a result of runaway inflation during the 1970s, US interest rates in the absence of regulations were typically higher than the interest rate ceilings. As a consequence, Regulation Q posted a binding constraint on US commercial banks. During this period, US authorities also introduced tighter measures to control the free flow of capital between the onshore and offshore markets.

(3) 1980-1985: This is a transitional period where the Monetary Control Act (1980) set the timetable to phase out Regulation Q in five years.

(4) 1986-1995: In this period, Regulation Q was completely phased out and the two markets were basically integrated. It is worth noting that the end point 1995 was chosen so as to make the length of this period comparable to previous sub-periods.

3.3 Empirical Results

3.3.1 Impulse Response Functions

Based on an estimated vector auto-regressive (VAR) model, IRF can be computed that measures the response of the endogenous variables to one unit of idiosyncratic shock. It shows the first-round impact as well as the time path for the initial impact to phase out completely. Although the VAR model does not explicitly model the time-varying variance-covariance, the IRF graphs can provide some idea about the impact of a same-market and cross-market shock over various sub-periods.

Since the focus of this study is the onshore market, Figure 4 presents the IRF's of the US one-month rates in reaction to same-market and cross-market shocks.[19] Three points are worth noting. First, the

[19] The impulse-response functions of the three-month rates and six-month rates show similar patterns. For simplicity, these graphs are not presented in this paper.

impact of a shock from the Eurodollar market on the US domestic interest rate increases over time, suggesting that the offshore market had an increasing influence on the onshore market. During the first sub-period, the cross-market impact is generally small. Eventually, after Regulation Q was completely phased out in sub-period 4, the impact are larger. Second, the time for the impact of a shock to fully dissipate shortens over time. In the first two sub-periods, it takes three weeks for the bulk of the shock to phase out. However, during the last two sub-periods, it only takes two weeks. These findings suggest that as the onshore and offshore markets became more integrated, the markets were increasingly efficient in reflecting new information. Third, even though the influence of the Eurodollar market increases over time, the spillover impact of a shock from the offshore market on to US rates was smaller than that of a shock from the onshore market itself. For all the sub-periods in 1964-1995, a shock originating from the US might have up to five times more impact on US interest rates than a shock originating from the Eurodollar market. However, the latter's impact on US interest rates increases over time and takes a shorter time to fully dissipate (from 4-5 weeks in the 1960s to 2-3 weeks in the 1990s).

3.3.2 Spillover Effect on Market Volatilities

The results from the bivariate GARCH model (equation (1)) in Section 3.1 are presented in Table 2. First, in all the sub-periods and for interest rates of all tenors, the volatility spillover between US rates and Eurodollar rates are found to be bi-directional. In most of the cases, these spillover effects are found to be statistically significant. The economic interpretation is that the onshore and offshore markets are closely connected even in the early stage of the offshore market development. Therefore, an idiosyncratic shock (e.g. unexpected changes in monetary policies) in any market is immediately transmitted to the other market, resulting in greater fluctuations in the other market.

Second, the results suggest that US interest rate regulations and other capital control measures significantly alter the magnitude of the volatility of the spillovers. In particular, when the Regulation Q interest rate ceilings became binding on US commercial banks in the sub-period 2 (1971-1979), volatility spillovers between the two markets were much more subdued. For example, for the one-month interest rate, the US-to-Eurodollar spillover effects decreased to 0.0091, from the 1.8427 in the preceding sub-period. Similar declines were found in other tenors. This suggests that US banking regulations, to some extent, separated the onshore and offshore markets. As a result, either market is relatively insulated from shocks to the other. In reaction to a shock from the offshore market, the US domestic market reacted moderately in the sense that its fluctuations did not increase by too much.

Third, a comparison of the results between sub-period 1 and 4 suggests that relative market size may be an important factor in affecting the magnitude of the volatility spillover between the two markets. When the Eurodollar market was still relatively underdeveloped in sub-period 1, US-to-Eurodollar spillovers were much larger than Eurodollar-to-US spillovers. For example, in the case of the 1-month interest rates, the size of the spillover effects was estimated to be 1.8427 and 0.0096 respectively. However, after the rapid growth of the Eurodollar market in the 1970s and 1980s, its impact on the

volatility of the onshore market was more prominent. During the last sub-period, the Eurodollar-to-US volatility spillover effect of the 1-month interest rate was estimated to be 0.7561, which was remarkably larger than the 0.1318 for the US-to-Eurodollar spillovers. This suggests that, with the growth of the offshore market, onshore regulations play an increasingly important role in containing any spillover effects.

3.3.3 Spillover Effects on Market Levels

Table 3 shows the cross-market spillovers on the mean level of interest rates. The results suggest that spillover effects are also associated with US banking regulations.

During the first sub-period (1964-1970), spillover effects are found to be insignificant, suggesting that at that time the offshore Eurodollar market was still in an early stage of development, and therefore its interaction with the onshore US market through the mean levels was weak. During the second sub-period (1971-79) when Regulation Q became a binding constraint on US banks and other regulations were in full force, the mean spillover effect was found to be significant. In addition, the magnitude of a shock from the US on the offshore Eurodollar market is found to be greater than a shock the other way round. For example, the US-to-Eurodollar mean spillover is estimated to be 0.192, versus the Eurodollar-to-US spillover of 0.0691. During the third sub-period when Regulation Q was being phased out (1980-85), irregular patterns are found, and in some cases the estimated mean spillover effects are not significant, suggesting that the financial markets were in a stage of adjustment to the new regime change. It is found that during the last sub-period (1986-1995) in which deregulation was completed, the US-to-Eurodollar and Eurodollar-to-US mean spillover effects had a similar magnitude, suggesting that once the regulatory constraints were lifted, the onshore and offshore markets became more integrated, and therefore the two-way spillover effects were significant and of a similar magnitude in most cases.

4. Empirical Study of CNY and CNH Markets

4.1 Econometric Models

For cross-market spillovers, the econometric model is essentially the same as the one used for the analysis of the Eurodollar market except for two modifications. First, a control variable is added to the mean equations so that global shocks affecting both the CNY and CNH markets can be controlled for[20]. Second, since cointegration relationship is found for the CNY and CNH markets[21], a vector error correction (VEC) form is specified in the mean equations.

[20] In our study, this is proxied by the S&P VIX index, which is widely regarded as a major indicator of global investor sentiment and financial market volatility since its launch in 1993.

[21] See Section 4.2 for details.

In addition to the analysis of cross-market spillovers, as the disparities of the DF implied yields in the CNH and the Mainland markets are more apparent than the case of the Eurodollar market, it is of interest to evaluate the relative contribution of these two markets in the price discovery process[22]. In the research literature, the indicators based on the permanent-transitory model of Gonzalo and Granger (1995) and the information share model of Hasbrouck (1995), hereafter GG indicator and H indicator respectively, are commonly used. Since these indicators provide different perspectives on the price discovery process and hence are complementary[23], we use both in our analysis. Both indicators are based on a vector error correction (VEC) model.

Under this framework, the GG indicator is defined as:

$$GG = \frac{\lambda_{off}}{\lambda_{off} - \lambda_{on}} \tag{2}$$

where λ_{on} and λ_{off} are the VEC coefficients for CNY and CNH respectively

In essence, the GG indicator is the ratio of the speed of adjustment in the two markets, and it is theoretically bounded between 0 and 1. When this indicator is close to 0, it implies that the CNH market plays a leading role in price discovery and the Mainland market moves afterwards to correct for pricing discrepancies. When the measure is close to 1, the dynamics work in the opposite direction, i.e. the Mainland market leads the CNH market. When the indicator is close to 0.5, both markets contribute to price discovery and there is no clear evidence on which market is more important.

Regarding the H indicator, since the ordering of variables is crucial for this indicator, it is defined by the following lower and upper bounds:

$$H_{lower} = \frac{\lambda_{off}^2 \left(\sigma_{on}^2 - \left(\sigma_{on,off}^2/\sigma_{off}^2\right)\right)}{\lambda_{off}^2\sigma_{on}^2 - 2\lambda_{on}\lambda_{off}\sigma_{on,off} + \lambda_{on}^2\sigma_{off}^2} \tag{3a}$$

$$H_{upper} = \frac{\left(\lambda_{off}\sigma_{on} - \lambda_{on}\left(\sigma_{on,off}/\sigma_{on}\right)\right)^2}{\lambda_{off}^2\sigma_{on}^2 - 2\lambda_{on}\lambda_{off}\sigma_{on,off} + \lambda_{on}^2\sigma_{off}^2} \tag{3b}$$

Unlike the GG indicator, the H indicator takes into account the role of the variance of the innovations in the two markets. If the midpoint of the H lower and upper bounds for a market is less than 0.5, the

[22] Price discovery indicators are not computed for the Eurodollar market since only weekly data are available for the early years of this market, which is not granular enough to capture the dynamics of a price discovery process that takes place in less than a week.

[23] The H indicator decomposes the variance of the implicit efficient price, and attributes the leading role of price discovery to the market that accounts for a larger share of this variance. In comparison, the GG indicator decomposes the permanent component of market price and attributes the leading role to the market that adjusts least to the price movements in the other markets. For further discussion of the two indicators, see Baillie et al (2002) and De Jong (2002).

CNH market plays a more dominant role in the price discovery process. If this midpoint is larger than 0.5, the Mainland market plays a more dominant role.

4.2 Data Source

The data source for the analysis of the CNH and Mainland China markets is RMB DF implied yields. The Mainland DF market was launched shortly after the RMB managed float regime was introduced in July 2005, whereas the Hong Kong DF market started in September 2010 as the Clearing Agreement laid the foundation of the CNH market. While the RMB non-deliverable forward (NDF) in Hong Kong has a longer history dating back to the late 1990s, this market has been eclipsed by the DF market in recent years, reflecting advantages of DF over NDF contracts[24]. First, the deliverability of DF contracts is an appealing feature to corporate users that need RMB for trade settlements and other transaction purposes. Second, since NDF contracts settle at the official central parity rate, NDF market participants may be exposed to significant basis risk due to the widening of the RMB/USD foreign exchange trading band in recent years[25] as well as the tendency for actual trading to occur near the edges of the band. Third, participation in the NDF market is not permitted in the mandates of some institutional investors, notably official investors, but participation in the CNH DF market is usually allowed[26].

The data used in this study consists of daily implied yields from the RMB DF contracts traded in the Mainland and CNH markets during 2011-2013. DF-implied yields, which are commonly used in studies related to onshore-offshore market interactions[27], can be interpreted as the link between the spot and forward exchange rates of RMB, on the condition that covered interest rate parity (CIP) holds. Given the active trading of DF in both markets, DF implied yields should be able to capture RMB forward premium dynamics. At daily frequency, the data series are long enough for more rigorous econometric analysis. Specifically, DF implied yield is implicitly defined by the following CIP condition:

$$F = S(1 + y^{RMB})/(1 + y^{USD}) \quad (4)$$

where F is the RMB DF exchange rate against the US dollar, S the spot RMB/USD exchange rate, y^{USD} the US dollar interest rate and y^{RMB} the DF-implied yield. The daily close of the DF obtained from Bloomberg is used to compute the implied yield. After taking into account maturity adjustment, the annualised DF implied yield could be backed out as follows:

[24] Although the BIS Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity showed that as at April 2013, the daily turnover of RMB DF in CNH (US$7.1 billion) was still lower than the NDF market (US$17 billion), market information suggests that since then, the NDF market has been losing importance to the DF market.

[25] The RMB/USD trading band was widened to +/-0.5% from +/-0.3% in May 2007, and then to +/-1% in April 2012, and then to +/-2% in March 2014.

[26] For details, see McCauley, Shu and Ma (2014) and Chow (2013).

[27] For example, Ma and McCauley (2007), Cheung and Herrala (2014)

$$y^{RMB} = \left(F * \frac{1 + (LIBOR * M/12)}{S} - 1 \right) * \left(\frac{12}{M} \right) \quad (5)$$

where LIBOR is the London Interbank Offered Rate for US dollar and M is the maturity of LIBOR in terms of months[28]. These yields have maturities ranging from one to twelve months[29]. The pairs of implied yields for the Mainland and CNH markets are shown in Figure 5. It is noteworthy that the two series appear to be move close to each other except for occasional periods of wider disparity, suggesting a close relationship between the two markets[30]. We have conducted the Engle-Granger test and Phillips-Ouliaris test and found that the pairs of Mainland and CNH DF implied yields for all maturities are co-integrated.

The descriptive statistics of these implied yields are shown in Table 4. It is obvious that each pair of Mainland and CNH yields of the same maturity has a similar mean and standard deviation, which supports the view that they are closely related. Note that the minimum levels of the yields are negative. As argued by Ma and McCauley (2007), the DF implied yield is not constrained by a zero lower bound and could be substantially negative. If capital controls are effective in constraining arbitrage between the onshore and offshore money markets, there may be a difference between the onshore and offshore yield , and the sign of the yield gap may say something about prevailing market conditions: a positive sign implies appreciation pressure on the home currency in the presence of capital controls and vice versa.

4.3 Empirical Results

4.3.1 Impulse Response Functions

Figure 6 depicts the IRF of the one-month implied yields as an example. There are two observations worth noting. First, for the Mainland DF implied yields, market movements reacting to a one unit of shock originating from the Mainland itself (same-market shock) are more drastic that those triggered by a one unit of shock from CNH (cross-market shock). The knock-on impact of a shock from the Mainland was 20-25 bps in 2013, whereas the impact of a shock from the CNH market was at most 2-3 bps. Second, for the CNH DF implied yields, the impact of a cross-market shock (the blue line in panel B) becomes more significant over time, with the knock-on impact of a shock increasing from about 1 bps in 2011 to 15 bps in 2013.

[28] Since US dollar interest rates for the Mainland domestic market are not available on a daily basis, the LIBOR US dollar interest rate is used as a proxy for the computation of the Mainland DF implied yield.

[29] In order to capture cross-market dynamics, data frequency should be as high as available data allows. Therefore, daily frequency is chosen although this does not match DF implied yields maturities that range from 1 month to 12 months. This practice is also found in the research literature, e.g. Maziad and Kang (2012).

[30] For a discussion of the disparities of Mainland and CNH RMB forward exchange rates, see Li, Hui and Chung (2012).

4.3.2 Cross-Market Spillovers

To further examine their contribution to the volatility in the two markets, we apply variance decomposition techniques proposed by Diebold and Yilmaz (2009, 2012) and find that Mainland shocks have played an increasingly important role in driving volatility in the CNH market. As shown in Table 5, up to 61% of the average volatility of DF implied yields in the CNH market in 2013 are attributable to shocks originating from the Mainland, compared with only 4% in 2011. For the Mainland DF implied yields, such a pattern is not apparent, as shocks from the Mainland market itself consistently play a leading role in driving the forward premium, accounting for approximately 85% of market volatility throughout 2011-13.

Table 6 presents the estimation results of the bivariate GARCH model specified in Section 4.1. The results suggest that cross-market spillovers were very limited in 2011-2012 as most of the pairs of estimated coefficients are not statistically significant, and the pattern of the interactions is not clear-cut. Nonetheless, cross-market spillovers appear to be two-way in 2013, suggesting increasing integration between the two markets. In particular, spillovers from the Mainland onto the CNH market are found to be larger than spillovers in the opposite direction in most cases. Wald tests further confirm that the differences between the two spillovers are statistically significant. These results probably reflect the fact that the CNH market, though rapidly growing, is still small compared to the Mainland market[31], and possibly subject to more onshore influences. Furthermore, the increasing use of RMB in cross-border trade and other transactions, as well as the relaxation of the RMB trading band in recent years, might have allowed more scope for the Mainland RMB market to affect the CNH market since 2013.

4.3.3 Contributions to Price Discovery

As shown in Table 7, both the GG and the H indicators suggest that neither market played a leading role in the price discovery of DF implied yields, suggesting that the two markets contribute to different aspects of the price discovery process. On the one hand, as the CNH market is subject to fewer regulations than the Mainland market, it is probably more flexible in reflecting supply and demand conditions. Also, as an international financial centre, Hong Kong is in a better position to transmit global financial conditions relevant to RMB forward rates. On the other hand, to the extent that market movements are driven by changes in policies or financial conditions in the Mainland domestic market, market participants located in the Mainland might be in a better position to incorporate such information into market prices.

[31] As a proxy indicator, RMB deposits in the Hong Kong banking sector totaled RMB860 billion at the end of 2013, around 1% of RMB deposits in the Mainland. Given this contrast in size, it is not surprising that the CNH market is more subject to onshore influences than the other way round.

5. Concluding Remarks

In summary, for the Eurodollar market, the main findings of the empirical study are as follows. First, a same-market shock was found to have a larger impact than a cross-market shock on interest rates. Second, onshore regulations were effective in containing spillover effects between the offshore and the onshore markets. Compared to other sub-periods, volatility spillovers was found to be the weakest in the 1970s when Regulation Q and capital control measures were in full force. Third, relative market size might explain the magnitude of cross-market spillovers on volatility. As the Eurodollar market grew rapidly since the early 1980s, its volatility spillover effects onto the US market became more tangible, and onshore-offshore interactions became truly two-way. Nonetheless, as shown in Section 2.3, the Federal Reserve still retained effective control of domestic bank credit primarily through Regulation D[32].

Regarding the CNH market, the key results are as follows. First, as the CNH market further develops, its interaction with the Mainland market will likely become increasingly two-way. Spillovers from the Mainland to CNH were found to be larger than spillovers in the opposite direction in most cases. This suggests that the Mainland market, given its huge size compared to the CNH market and the recent relaxation of capital control measures and other regulations[33], plays a dominant role in the transmission of volatility between the two markets. Second, we found that both the Mainland and the CNH market have played an important role in the price discovery process of RMB forward markets in different aspects.

Evidence of cross-market spillovers suggests that onshore and offshore markets are influencing each other through various channels. Understanding how these channels work is useful. Theoretically, there are two possible channels – one based on cross-market arbitrage and the other based on cross-market information differentials. For the case of the Eurodollar market, given that international capital flows are largely unrestricted, it is likely that both channels are working. However, for the case of the CNH market, cross-market arbitrage is unlikely to be a major channel for spillovers in view of the effectiveness of Mainland's capital control measures. Therefore, the major channel for spillovers is likely to be based on information differentials between the two markets. To illustrate, market participants in one market may perceive that prices in the other market are more effective in reflecting certain types of information. Thus, price movements in one market may serve as useful indicators, prompting market participants in the other market to follow suit. For example, Maziad and Jang (2012) argue that market participants in the CNH market might interpret forward rate movements in the onshore markets as proxy indicators reflecting, say, monetary conditions on the Mainland. On the other hand, onshore market participants might perceive that forward rate movements in the CNH

[32] For details, see He and McCauley (2010)

[33] For example, in July 2013 commercial banks of the Mainland were granted more flexibility in setting both lending and borrowing interest rates.

market better reflect global market conditions due to Hong Kong's openness and connectedness with the global financial markets.

To conclude, with reference to the historical experience of the Eurodollar market, there are reasons to expect that two-way interaction between the CNH and the Mainland markets to increase as the CNH market further develops. As the Mainland continues to liberalise capital account transactions, the arbitrage channel is expected to become increasingly crucial to cross-market interactions, though this is unlikely to happen in the near future due to the gradualist approach adopted by the Mainland authorities in implementing reforms. During this long process of adjustment, the Mainland market is expected to continue to play a leading role in the onshore-offshore money and foreign exchange market interactions, since these markets will be ultimately dominated by the monetary policy stance of the onshore authorities. As the experience of the Eurodollar market suggests, onshore authorities retain regulatory tools to control monetary conditions in the domestic market. Furthermore, the monetary authorities of Hong Kong and the Mainland have maintained a close working relationship since the launch of Hong Kong's RMB banking business in 2004. Such onshore-offshore cooperation, which is absent in the case of the Eurodollar market, may provide an additional safeguard to contain cross-market spillovers and help to pre-empt potential threats to the stability of both markets.

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Table 1. Descriptive Statistics of the US and Eurodollar Interest Rates

	Eurodollar market			US domestic market		
	1-month	3-month	6-month	1-month	3-month	6-month
Mean	6.47	6.64	6.79	6.19	6.30	6.43
Median	5.81	6.00	6.19	5.59	5.73	5.85
Maximum	22.63	21.88	19.81	20.76	20.23	18.34
Minimum	0.16	0.19	0.32	0.15	0.19	0.28
Std. Dev.	3.55	3.57	3.53	3.33	3.32	3.29
Skewness	0.94	0.91	0.81	0.91	0.89	0.82
Kurtosis	4.72	4.49	4.14	4.75	4.63	4.34
Observations	2332	2332	2332	2332	2332	2332

Note: The statistics are for the whole sample period 1964-2010.

Source: Federal Reserve

Table 2. Shock Spillover between US Domestic and Eurodollar Market

	Maturity of interest rates		
	1-month	3-month	6-month
1964-70			
US-to-Eurodollar	1.8427***	0.7828***	1.6114***
Eurodollar-to-US	0.0096***	0.0154***	0.0674***
1971-79			
US-to-Eurodollar	0.0091***	0.0038**	0.0011
Eurodollar-to-US	0.0045***	0.0055***	0.0006
1980-85			
US-to-Eurodollar	0.0663***	0.1224**	0.0351
Eurodollar-to-US	0.0174***	0.1376***	0.1217***
1986-95			
US-to-Eurodollar	0.1318***	0.0004	0.0061***
Eurodollar-to-US	0.7561**	0.2884***	0.1116***

Notes:
1. Larger the coefficients, stronger the cross-market spillover.
2. ***, ** and * denote significance at 1%, 5% and 10% levels respectively.

Table 3. Mean Spillover between US Domestic and Eurodollar Market

	Maturity of interest rates		
	1-month	3-month	6-month
1964-70			
US-to-Eurodollar	1.6609	-0.8869	0.0009
Eurodollar-to-US	0.0344	0.0815	-0.0471
1971-79			
US-to-Eurodollar	0.1920**	0.2725***	0.4967***
Eurodollar-to-US	0.0691***	0.1247***	0.1155***
1980-85			
US-to-Eurodollar	0.1064	0.4978***	0.4865***
Eurodollar-to-US	0.4176***	0.0728	0.1405
1986-95			
US-to-Eurodollar	0.3623***	0.3485***	0.3735***
Eurodollar-to-US	0.3420***	0.2394***	0.1834***

Notes:
1. Larger the coefficients, stronger the cross-market spillover.
2. ***, ** and * denote significance at 1%, 5% and 10% levels respectively.

Table 4. Descriptive Statistics of the Renminbi DF Implied Yields

	Mainland market				CNH market			
	1-month	3-month	6-month	12-month	1-month	3-month	6-month	12-month
Mean	1.62	1.47	1.39	1.49	1.60	1.64	1.66	1.75
Median	1.66	1.46	1.40	1.54	1.56	1.79	1.98	2.13
Maximum	6.83	4.55	3.76	3.61	6.26	4.62	3.86	3.64
Minimum	-3.95	-1.67	-2.59	-1.12	-1.41	-1.36	-1.39	-1.05
Std. Dev.	1.40	1.34	1.29	1.21	1.36	1.32	1.32	1.27
Skewness	-0.15	-0.12	-0.25	-0.34	0.08	-0.37	-0.57	-0.70
Kurtosis	3.18	2.40	2.34	2.06	2.46	2.19	2.22	2.24
Observations	739	733	736	735	754	751	751	756

Note: The statistics are for the sample period 2011-2013.

Source: Bloomberg

Table 5. Volatility Spillover Table[34]

From:	2011		2012		2013	
To:	Mainland	CNH	Mainland	CNH	Mainland	CNH
Maturity: 1 month						
Mainland	93	7	91.6	8.4	92.5	7.5
CNH	1	99	20.8	79.2	78.6	21.4
Maturity: 3 month						
Mainland	85.7	14.3	87.7	12.3	87.6	12.4
CNH	8.4	91.6	23.8	76.2	69.7	30.3
Maturity: 6 month						
Mainland	84.2	15.8	80	20	87.0	13.0
CNH	0.3	99.7	32.1	67.9	54.0	46.0
Maturity: 12 month						
Mainland	77.5	22.5	81.3	18.7	77.7	22.3
CNH	7.9	92.1	44.5	55.5	41.4	58.6
Average						
Mainland	**85.1**	**14.9**	**85.2**	**14.9**	**86.2**	**13.8**
CNH	**4.4**	**95.6**	**30.3**	**69.7**	**60.9**	**39.1**

Note: All figures are in per cent. For example, for the 1-month implied yields, 92.5% of the volatilities in the Mainland market are attributable to Mainland (same-market) shocks, whereas 7.5% are transmitted from CNH.

[34] Based on Diebold and Yilmaz (2012)

Table 6. Shock Spillover between Mainland and CNH Market

	Maturity of DF implied yields			
	1-month	3-month	6-month	12-month
2011				
Mainland-to-CNH	0.000	0.004	0.000	0.024*
CNH-to-Mainland	0.003	0.000	0.003	0.003**
2012				
Mainland-to-CNH	0.002	0.003	0.004	0.006
CNH-to-Mainland	0.000	0.094***	0.006	0.179***
2013				
Mainland-to-CNH	0.447***	0.056***	0.480***	0.103***
CNH-to-Mainland	0.110***	0.048***	0.224***	0.173***

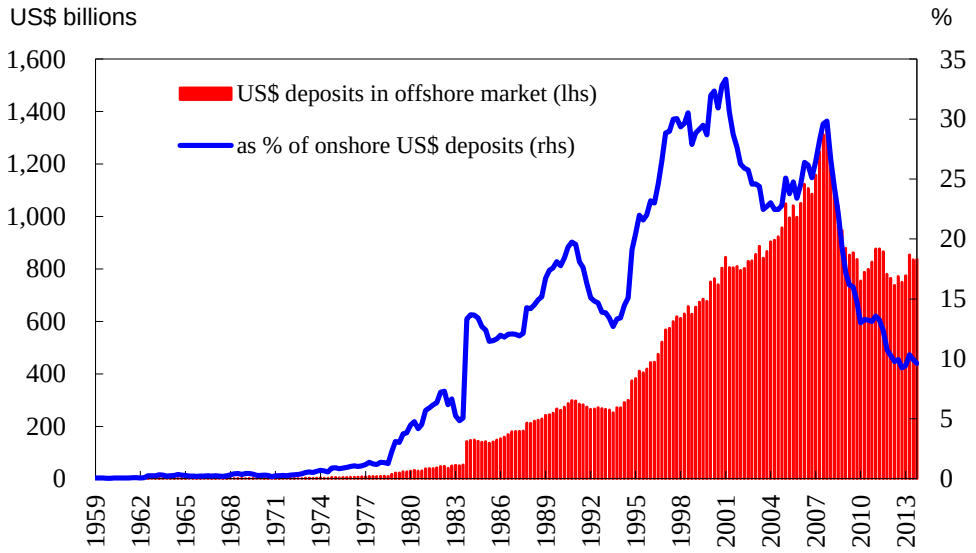
Notes:
1. Larger the coefficients, stronger the cross-market shock spillover.
2. ***, ** and * denote significance at 1%, 5% and 10% levels respectively.

Table 7. Price Discovery Functioning of Mainland China and CNH Markets

	Maturity of DF implied yields			
	1-month	3-month	6-month	12-month
GG indicator	0.302	0.548	0.832	-0.149
H indicator	0.309	0.579	0.832	0.081
Leading role in price discovery	CNH	Mainland	Mainland	CNH

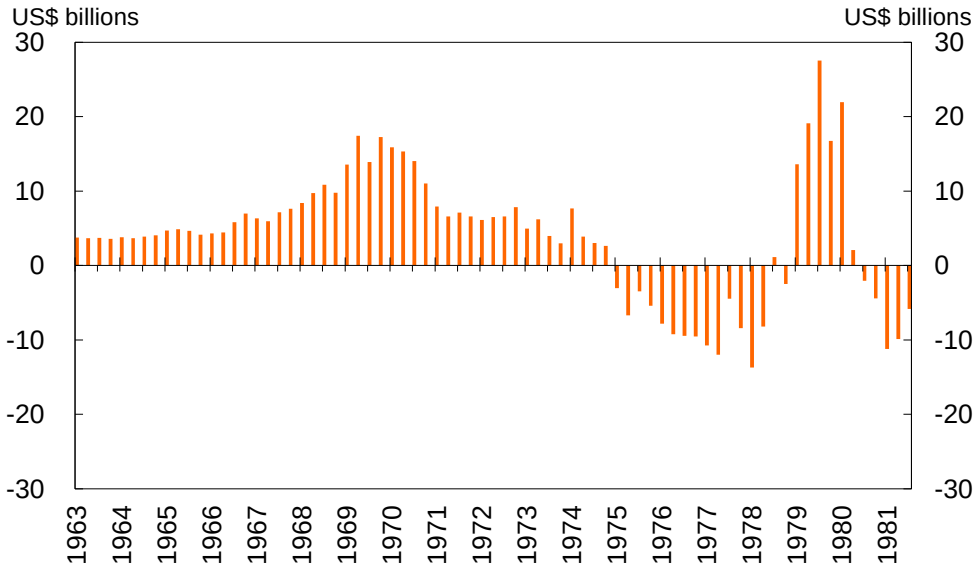
Note: GG indicator and H indicator are calculated based on the permanent-transitory model of Gonzalo and Granger (1995) and the information share model of Hasbrouck (1995) respectively. They provide a relative measure of price discovery across multiple markets instruments. Measure less than 0.5 here represents a leading role of the CNH market in the price discovery process.

Figure 1. US Dollar Deposits in Foreign Countries[35]



Source: Federal Reserve.

Figure 2. US Banks' Net Borrowing from Their Offshore Branches

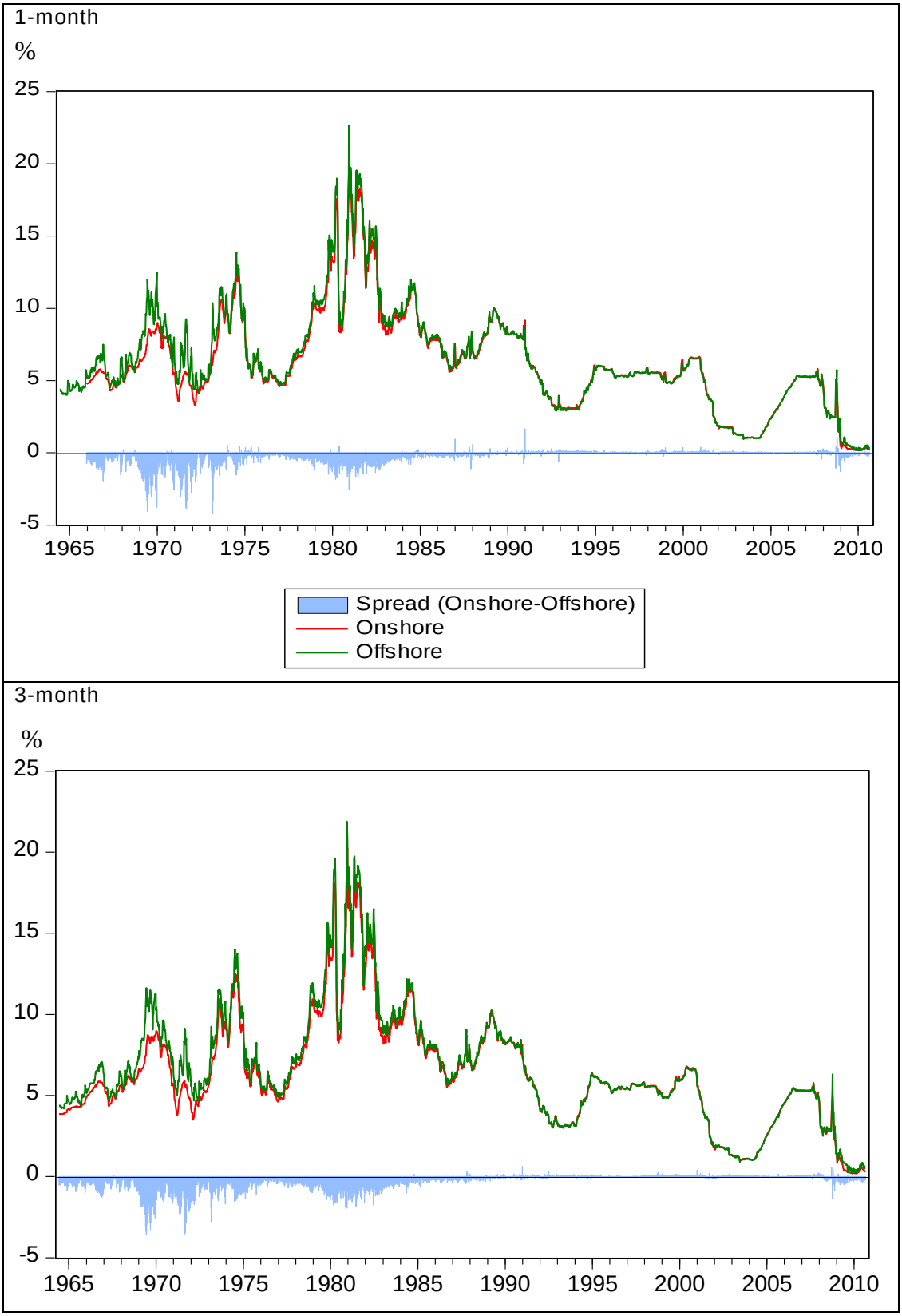


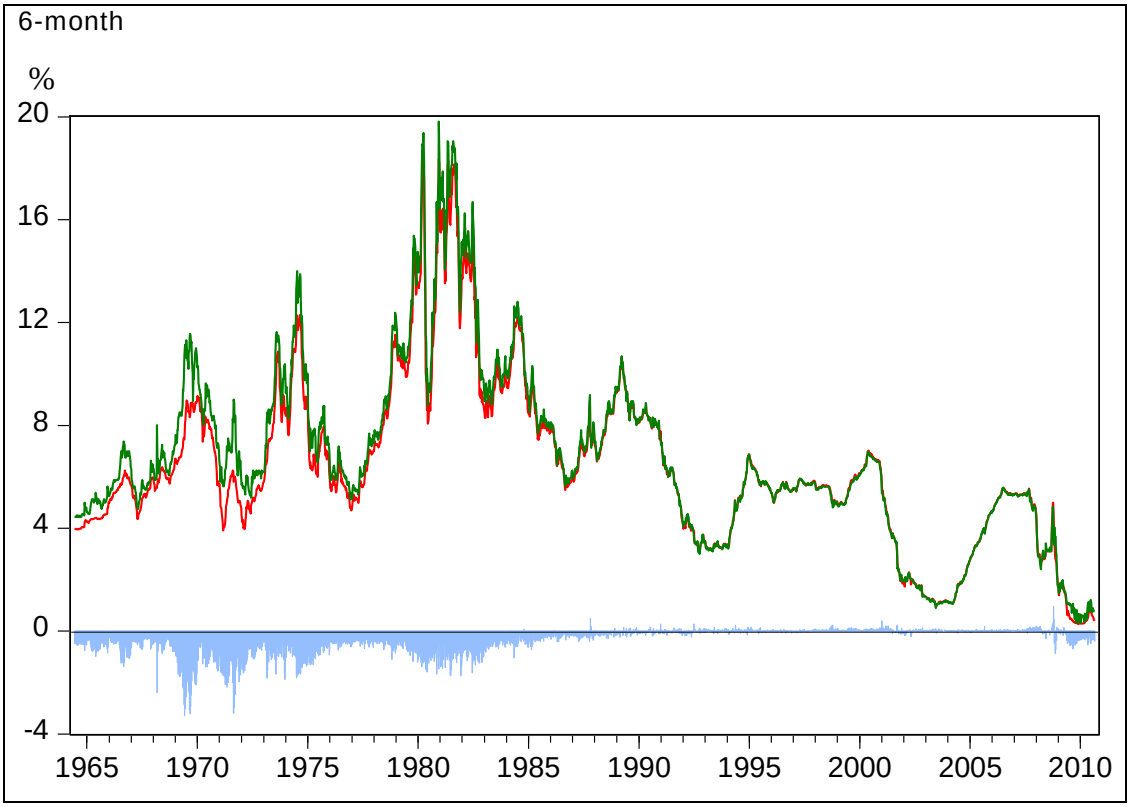
Note: Positive values represent net borrowings by US banks from their foreign branches while negative values represent net lending to foreign branches.

Source: Federal Reserve.

[35] US dollar deposits in foreign countries are deposits, including negotiable certificates of deposit, held in foreign financial institutions by private U.S. owners. Data on the deposit liabilities of foreign institutions are taken from the *Survey of Current Business*; figures on holdings of the deposits by U.S. sectors are estimated from reports of currency holdings filed with the Internal Revenue Service, from the Federal Reserve Board's *Survey of Consumer Finances*, from the *Quarterly Financial Report* , from *Statistics of Income* data published by the Internal Revenue Service, and from data collected by the Investment Company Institute.

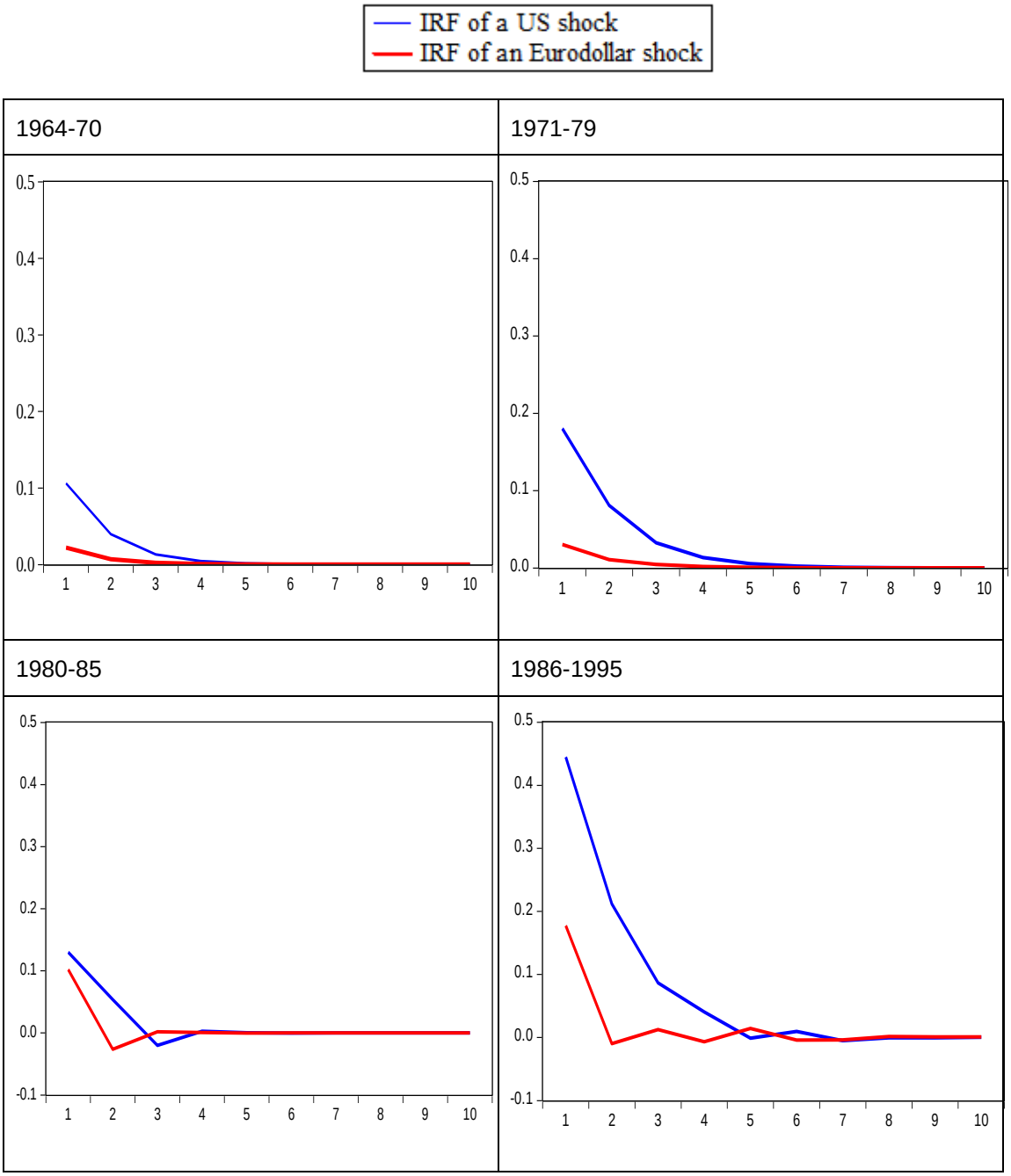
Figure 3. Eurodollar Rates and US Certificate of Deposit Rates





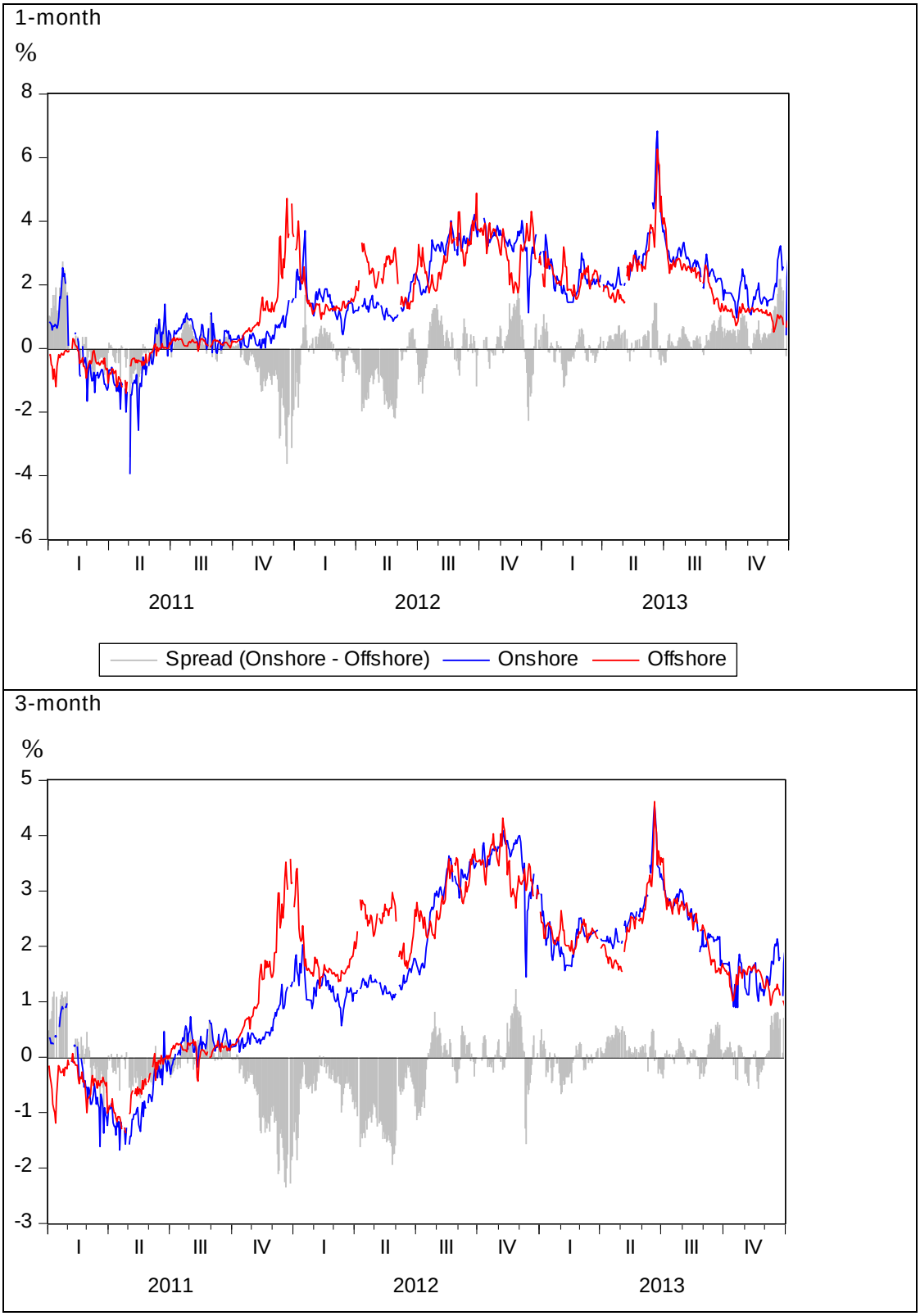
Source: Federal Reserve.

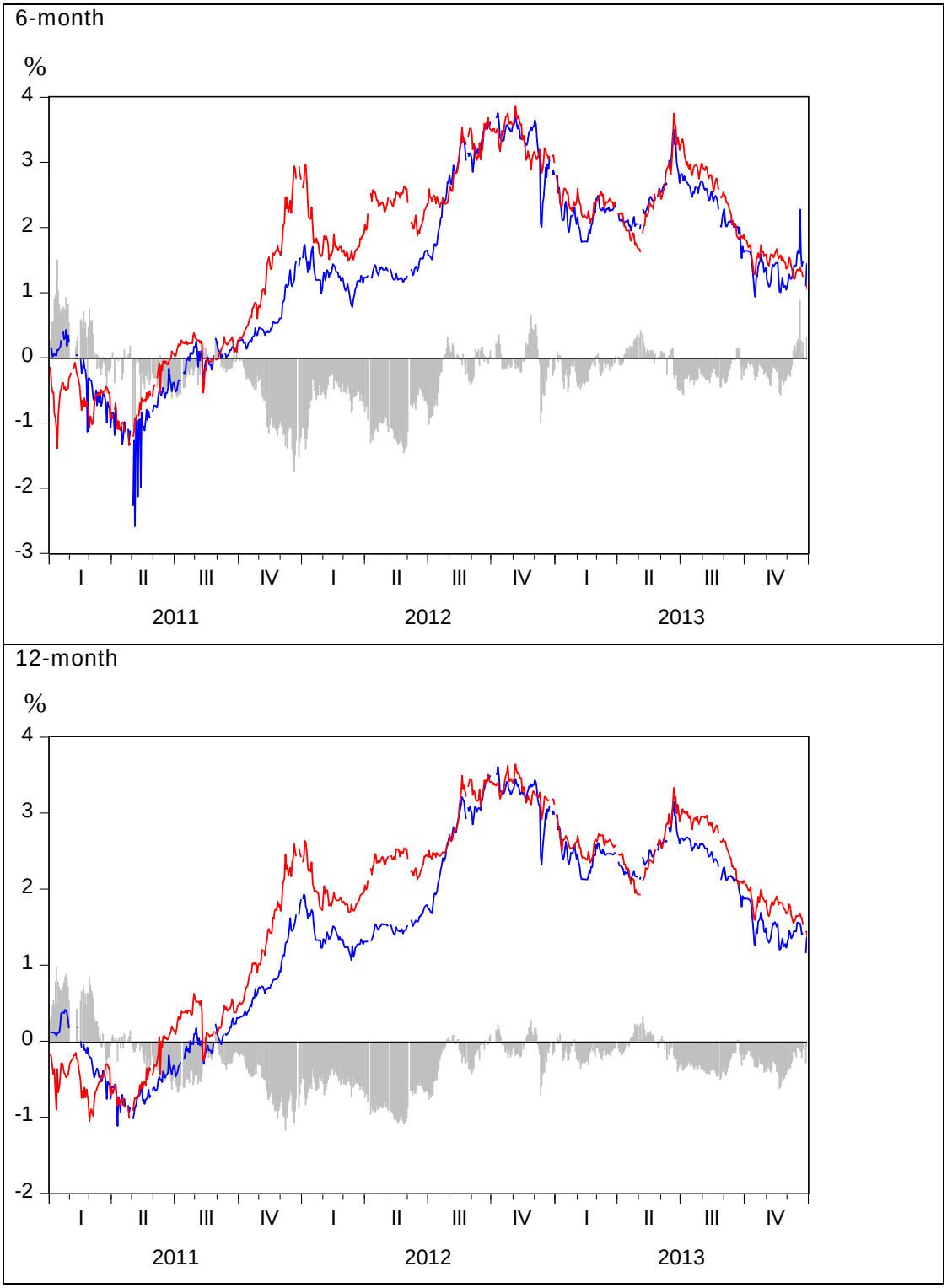
Figure 4. Impulse Response Functions: US Domestic 1-Month Rate



Note: The impulse response functions show the responses of the variable to Cholesky one S.D. innovations.

Figure 5. Mainland and CNH Forward Implied Yields





Source: estimates using data from Bloomberg

Figure 6. Impulse Response Functions of 1-Month DF Implied Yields

Note: The impulse response functions show the responses of the variable to Cholesky one S.D. innovations.

Appendix

History on the Development of the Eurodollar Market

Time	Policies and Economic Events	Characteristics
Late 1957	In the depth of a balance of payment crisis, UK prohibited using sterling to finance foreign trade between third parties	Banks in London began to use USD deposits.
July 1963	Interest Equalisation Tax was introduced in the US to discourage investing aboard	Worsening US balance of payments
Mar 1965	Voluntary foreign credit restraint program (FCRP) was introduced to limit US banks' foreign lending	Supply of funds to the Eurodollar market was restricted. Larger banks borrowed heavily from Eurodollar market through foreign branches
1966	Credit crunch; Fed pressured on the banks' reserve positions and amended Regulation Q that extended interest rate ceilings on thrift institutions	Liabilities of US banks to their foreign branches had risen 3 times from 1965; Eurodollars were in ample supply and played an important role in US banks' efforts to meet loan demands
Early 1967	Large movement of foreign funds into London money market coincided with a considerable easing of US domestic conditions	Banks reduced borrowing sharply; demand for business loans was relatively weak
June 1967	Foreign investors shifted substantial amounts of short-term sterling investments into Eurodollar market in response to the Middle East crisis	Foreign branch deposits surged again; Eurodollar market became a normal source of funds to be tapped for US banks
Jan 1968	Fed given authority to make FCRP mandatory	
1968-1969	US money market conditions tightened; Fed resumed and intensified credit restraint	Net borrowing far exceeded the 1966 levels. Foreign branches bid up Eurodollar interest rates in order to satisfy home-office needs.
Oct 1969	Eurodollar reserve requirement of 10% imposed	

Time	Policies and Economic Events	Characteristics
Mid-1970	Relaxation of interest rate ceilings on US bank deposits	
Jan 1971	Eurodollar reserve requirement increased from 10% to 20%	
Mar 1973	End of Bretton Woods fixed exchange rate system	Central bank intervention in support of the dollar diminished substantially
June 1973	Eurodollar reserve requirement reduced from 20% to 8%	To encourage US banks to fund themselves from offshore sources (but failed) & to support the dollar in the foreign exchange market
Oct 1973	First oil price shock	Put downward pressure on Eurodollar rates
Jan 1974	FCRP was officially abolished	
May 1975	Eurodollar reserve requirement was reduced from 8% to 4%	Eurodollar market was operating more normally
1975-1978	External credit demands were strong	US banks gradually increased their net lending to their offshore branches
Aug 1978	Eurodollar reserve requirement was eliminated	
Early 1979	Euromarkets were flooded with new deposits in the wake of second oil price shock	Downward pressure on Eurodollar rates
Jan-Aug 1979	US banks quickly reversed net position (shifted from being net suppliers of funds to being net takers)	Effective cost of Eurodollar funds was less than effective cost of domestic funds
Oct 1979	Fed changed operating procedures and imposed 8% of marginal reserve requirements on managed liabilities aggregates (including Eurodollar borrowings and large CDs)	To enhance implementation of monetary policy and reduce inflationary momentum. US banks reduced net position with their own foreign branches to nearly zero

Time	Policies and Economic Events	Characteristics
Mar 1980	Fed implemented special credit restraint program to reduce ability of US banks to expand domestic credit, while foreign borrowers re-entered the Eurodollar market. Marginal reserve requirements on managed liabilities increased from 8% to 10%	Eurodollar moved up sharply. US banks transferred funds offshore due to strong external credit demands
May 1980	Marginal reserve requirements on managed liabilities were reduced from 10% to 5%	
July 1980	Marginal Eurodollar reserve requirements were eliminated	
Nov 1980	*Monetary Control Act* took effect to phase out Regulation Q over a period of 6 years	
Oct 1981	Eurodollar transactions settled in immediately available funds as opposed to one-day lag	
Dec 1981	International banking facilities (IBFs) established to allow US banks to be more competitive in conducting banking services with non-US residents	Non-US residents can conduct banking transactions in US free of any reserve requirements or interest rate limitations without costs of insurance by FDIC
Mar 1986	Regulation Q was completely phased out.	