

The Offshore Renminbi Exchange Rate: Microstructure and Links to the Onshore Market*

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ABSTRACT

A specialized microstructure dataset is used to study the CNH, the offshore renminbi foreign exchange rate. In accordance with the microstructure literature, find that CNH order flow, a measure of net buying demand offer good explanatory power. We find that the offshore CNH exchange rate has an increasing impact on the onshore rate, and has significant predictive power for the official RMB central parity rate. The CNH order flow also affects the onshore RMB exchange rate and the central parity rate.

JEL Codes: F31, F33, G14, G15, G21, G28

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1. Introduction

On the heels of China's strong economic performance that includes phenomenal economic growth, large trade surplus, and huge reserve buildup over the last decade,¹ the discussions of internationalizing the Chinese currency renminbi (RMB) have reverberated in the global community. Indeed, there is a rapid increase in the international use of the RMB over the past few years. According to the latest triennial survey of foreign exchange turnover, the RMB was the 9th most actively traded currency in the 2013 survey while it ranked the 17th in the previous survey (Bank of International Settlements, 2013). In October 2013, the RMB surpassed the euro and Japanese yen and became the second most used currency in traditional trade finance covering letters of credit and collections, and was the number 12 payments currency of the world (SWIFT, 2013).² These increases are mainly contributed by expansion of offshore RMB activities.

The RMB internationalization initiative has implications for both the Chinese and the global economy. Some commentators view the initiative as a disguised component of reform efforts and an integral part of China's financial liberalization process. The experiences cumulated from offshore markets offer practical guidance to modernize the domestic financial sector. The coming of the RMB in the global financial market; similar to China's expansion into the trade arena, presents challenges to the incumbent major players including the US and its currency. It is anticipated that the geopolitical and geoeconomic landscapes will undergo substantial shifts when the RMB is becoming a full-fledged international currency.

While policymakers and academics are debating the motivations behind the policy of internationalizing RMB, and its prospects, the market has "created" a second exchange rate for the RMB that is deliverable and transacted in the offshore RMB market. Indeed, market practitioners view the RMB transacted in Hong Kong is different from the RMB in China, and they coined the RMB traded in Hong Kong as CNH instead of the usual trading symbol CNY.³ In the following, we use "RMB" as a generic reference to the Chinese currency renminbi, while CNY and CNH refer to the RMB currencies traded, respectively, onshore and offshore. Due to

¹ See Song, Storesletten and Zilibotti (2011) for a model of joint determination of these three outcomes.

² The top 5 countries using RMB for trade finance were China, Hong Kong, Singapore, Germany and Australia. The RMB was the number 20 payments currency of the World in January 2012.

³ However, CNY is (currently) the only official ISO currency code used internationally, SWIFT (2011).

the effectiveness of China's capital controls, the exchange rates of the RMB in the offshore and onshore locations could be different.

The CNH market in Hong Kong is different from the onshore RMB market that determines the CNY. For instance, the RMB trading in Hong Kong is not (directly) subject to the prevailing Chinese capital control regulations, which restrict capital flows between the onshore and markets overseas. The effective segregation makes it possible to have two distinct exchange rates for the same currency RMB. Despite Hong Kong is physically close to China, the CNH and CNY exchange rates are different because they are affected by supply and demand conditions in their respective markets, and complete cross-market arbitrage is prevented by capital control regulations imposed by China.

Hong Kong is the home of the largest offshore RMB center, and started CNH foreign exchange trading in 2010. What could be learned from the nascent CNH foreign exchange market? Potentially, the offshore market offers information on pricing the RMB currency in the absence of capital controls. The CNH exchange rate could shed some useful insights on the (unobserved) RMB exchange rate that is driven by market forces and its fundamental determinants. There is a caveat, however. The CNH exchange rate could deviate from the unobserved market determined RMB exchange rate because the demand and supply conditions in the offshore market could be different from those of the overall RMB market. Nevertheless, the offshore market presents a good environment to assess the implications of market forces for the RMB exchange rate.

Against this backdrop, we study the CNH exchange rate dynamics and its potential implications for the CNY exchange rate. It is quite well known that short- and medium-run developments of exchange rates are not well described by exchange rate models based on standard structural fundamentals and time-series characterizations (Cheung, Chinn and Pascual, 2005). In this study, we exploit the microstructure approach and examine the interactions between the CNH exchange rate and its order flow.⁴

The microstructure approach emphasizes the role of net demand pressure captured by, say, accumulated order flow in determining exchange rates (Evans, 2011; King, Osler and Rime, 2013; Lyons, 2001). Chinn and Moore (2011) show that the microstructure approach is relevant

⁴ Zhang, Chau and Zhang (2013) examine the RMB order flow data in the mainland Chinese market. The role of order flow could be restricted since the onshore trading is subject to heavy management and with limited participation of international investors.

for the monthly frequency, which presumably is of more interest to central banks. Besides the CNH order flow data, the current study considers data from the limit-order book. Both types of microstructure data are from the Reuters D2000-2 platform.

On the link between the CNH and CNY exchange rates, we study their causal interactions and the possible time-varying nature of the relationship. In addition, we examine the role of the officially determined RMB central parity rate in describing the two exchange rates of the currency.

In anticipation of results, we find that the CNH order flow has a strong explanatory power for the CNH exchange rate. On the interconnectedness of the offshore CNH and the onshore CNY, it is on the average that the CNH instead of the CNY adjusts towards their empirical long-run relationship. However, the relation is time-varying and there are periods in which the developments of the CNH are an important determinant of especially short-run dynamics of the CNY. Further the influence of the CNH seems to be stronger and that of the CNY seems to be weaker near the latter part of our sample period. Furthermore, in an out-of-sample forecasting exercise we find that the CNH variables; the return of the CNH exchange rate and the CNH order flow, but not the CNY exchange rate have significant predictive power for the official RMB central parity comes from the CNH market.

The next section presents the background information of the CNH market and describes the data on the CNH order flow and limit order imbalance. The main empirical exercise that covers a) the microstructure variables and the CNH exchange rate, and b) the interactions of offshore and onshore exchange rates are presented in Section 3. Section 4 reports results of some additional analyses. Some concluding remarks are given in Section 5.

2. The Offshore RMB Market and the CNH Order Flow

2.1 The Offshore RMB Market

Starting from 2004, Hong Kong has been China's designated testing ground of internationalizing the RMB. As recent as 2011, the policy of developing Hong Kong into a prime offshore RMB center was affirmed in China's 12th Five-Year (2011–2015). Despite competition from other offshore centers, Hong Kong has maintained its leading position and accounted for about 80% of global offshore RMB payment volumes (SWIFT, 2012).

China's choice is closely related to Hong Kong's unique economic and political status. After the sovereignty change in 1997, Hong Kong is a special administrative region of China and is allowed to maintain its own legal structure and financial system. Specifically, Hong Kong has its own currency, the Hong Kong dollar, and imposes no capital controls. The differences in the legal and financial systems make it relatively straightforward for China to institute specific rules and procedures to regulate cross-border RMB transactions with Hong Kong. Notwithstanding Hong Kong is part of its territory; China treats Hong Kong as an offshore market in terms of cross-border RMB business.

The Supplementary Memorandum signed by the Hong Kong Monetary Authority and the People's Bank of China on July 19, 2010 represents a milestone of the offshore RMB market in Hong Kong (Hong Kong Monetary Authorities, 2010). It literally endorses the spot CNH foreign exchange trading, among other RMB-linked products, in Hong Kong. As a result, Hong Kong has started deliverable interbank RMB foreign exchange trading, and the market has embraced the creation of the offshore CNH exchange rate, which is a "second" exchange rate of the RMB. Within a few years, the trading in the spot CNH has grown from almost nothing to an estimated average daily volume of around \$3 billion, and is dominated by transactions with cross-border counterparts.

2.2 *The Data*

We obtained the microstructure data from the Reuters D2000-2 system. Reuters is one of the leading suppliers of electronic interbank foreign exchange trading services.⁵ The Reuters platform is most likely the major electronic interbank platform for CNH-trading. While the trading in the newly developed CNH market could be done via direct bilateral dealing between participants, the anecdotal evidence of other currencies suggests that trading taken place on the Reuters platform should be quite well correlated with the market-wide trading in CNH.⁶

Our data include transaction information and bid and ask limit orders that are timed to the thousandth of a second. Following the literature, a transaction that takes place at the ask price is assigned a value of +1 and a transaction occurs at the bid price a value of -1. The daily variable is constructed by summing these signed transactions and is interpreted as a measure of net

⁵ One of its main competitors is the Electronic Broking Services (EBS).

⁶ Electronic trading of offshore RMB at Reuters D2000-2 was first under the Reuters code (RIC) CNY=D2 until March 18 2011, and after that as code CNH=D2.

intraday buy pressure. To account for changing activity over time, we normalized this daily measure using the number of trades during the day to obtain the order flow variable used in the price impact regression analysis. The accumulated order flow is the cumulative sum of the normalized variable. By focusing on the direction of market trades, the order flow variable assesses the net buying pressure.

Using the limit-order book, we constructed the limit-order imbalance variable that is given by the difference between the number of bid and offer limit orders, normalized by the trading volume. The imbalance variable measures the relative trading interest by liquidity providers (market makers) Liquidity providers are compensated by selling high (at the ask price) and buying low (at the bid price). The bid-offer spread covers the risk incurred in that the said transactions are not guaranteed, and that they may trade against informed players. However, if liquidity providers have stronger trading interest in one direction (e.g buying) they may post more bid limit orders than offer limit orders.

The evolution of the CNH exchange rate is plotted in Figure 1. For comparison purposes, we imposed the CNY exchange rate and the RMB central parity rate in the same Figure. All the rates are the per US dollar exchange rates. Due to the availability of data on CNH and its order flow, we study the sample period from September 27, 2010 to August 27, 2013. In passing, we note that the central parity rate (which is commonly referred to as the ‘fixing rate’) is posted by the China Foreign Exchange Trade System in the morning of every business day.⁷ The central parity is used to define the band within which the CNY exchange rate is allowed to fluctuate. On April 14, 2012, People’s Bank of China widened the daily trading band from +/- .5% to +/- 1 % around the daily central parity rate.

A few observations are in order. First, since the resumption of the ‘managed floating exchange regime’ on June 19, 2010 (People’s Bank of China, 2010), the value of the RMB fixing rate has been steadily appreciated, and its movement resembles an upward crawl against the dollar (Ma and McCauley, 2011). During the sample period, RMB appreciated by more than 8% against the US dollar.

⁷ The posting of the fixing rate is authorized by the People’s Bank of China. Together with the US dollar, the fixing rates of either other currencies; namely, euro, Japanese yen, Hong Kong dollar, British pound, Australian dollar, Canadian dollar, Malaysian ringgit, and Russian ruble. The central parity of RMB against the U.S. dollar is based on a weighted average of inquired prices from all market makers before the opening of the market in each business day.

Second, the variability of the CNY exchange rate is noticeably larger after the widening of its trading band on April 2012. Third, The CNH exchange rate is more volatile than the CNY rate.

Fourth, while the CNH and CNY exchange rates usually track each other quite well, there are episodes in which they display a large disparity. For instance, the CNH had a large premium over CNY in the third quarter of 2010. The premium is usually attributed to a liquidity squeeze due to a stronger-than-expected demand for CNH for cross-border trade settlement. The premium subsided when the Hong Kong Monetary Authority activated its CNH liquidity provision through the swap arrangement with the People's Bank of China.

Fifth, the CNH suffered its largest discount to CNY in September 2011. The sell-off of CNH was associated with the surge in the global market risk that led to unwinding of emerging market currencies including the CNH.

Figure 2 graphs the CNH exchange rate and its accumulated order flow. With the exception of the late third quarter and the fourth quarter of 2011, the order flow and CNH exchange appear to move in tandem. The formal statistical analysis of these two variables is presented in the next Section.

3. Empirical analysis

In the following subsections, we study the links of the CNH exchange rate to a) its order flow, and b) its onshore counterpart.

3.1 CNH and Order Flow

Evans and Lyons (2002) present a model based on portfolio adjustment to illustrate the role of order flow in determining an exchange rate. The net market demand effect as captured by order flow in the current context could be examined by the regression

$$\Delta H_t = \alpha + \beta \Delta X_t + \gamma \Delta F_t + \varepsilon_t, \quad (1)$$

where ΔH_t is the return of the CNH exchange rate measured by its first log difference, ΔX_t is the CNH order flow, F_t is the three-month CNH and US dollar interest rate differential that represents effects of fundamentals, and ε_t is the regression error term. The definitions and sources of these and other variables used in the study are listed in the Appendix.

The results of estimating (1) are presented in Table 1. The lagged CNH return is added to control for possible serial dependence. It turns out that the lagged return is insignificant in all cases considered. The result under column (1) shows that the interest rate differential exhibits no substantial explanatory power.

As CNH is among the group of emerging market currencies that are heavily affected by the market attitude toward risk – the so called risk-on and risk-off phenomenon, we include the change of the logarithm of the J.P. Morgan currency volatility index of emerging markets in the specification under column 2. The market volatility variable accounts for about 7% of CNH variations on the margin. The volatility index gauges the market's fear about the currencies of emerging countries. A high level of risk drives capital away from these emerging market currencies and, as a sympathy effect, away from CNH holdings.

The order flow variable that represents the net market pressure has the expected positive and significant effect. During the sample period, as graphed in Figure 2, the negative order flow moves down the value of the US dollar against the CNH. The marginal increase in the adjusted R-squares estimate is quite large – from 8% under column (2) to 20% under column (3). The finding attests the relevance of order flow in explaining the CNH exchange rate.

The limit-order imbalance variable has a significant and positive impact on the CNH exchange rate. While impatient informed traders place market orders, informed traders with long-lived information are likely to use limit-orders to secure better prices at the expense of execution uncertainty (Kaniel and Liu, 2006). In the current study, an increase of the imbalance by construction is indicative of the potential demand for the US dollar. Even though the coefficient estimate is small in magnitude, and its marginal explanatory power is small, its quality effect is in line with the usual interpretation.

In sum these results echo the extant evidence on effects of microstructure variables on exchange rate dynamics. The explanatory power of the specifications that incorporate order flow and order imbalance is quite high for high frequency exchange rate data.

There is a caveat, however. The contemporaneous relationship between CNH returns and order flow data presented in Table 1 could be driven by the effect of CNH on order flow – a high CNH exchange rate return attracts money flow into the currency. Another concern is that the first-difference specification may undermine the long-term linkage between CNH and its accumulated order flow.

The cointegration framework offers an alternative setting to investigate the role of microstructure variables. Specifically, we follow the literature and consider the trivariate system (H_t, X_t, F_t) . The unit root test results indicate that each of these data series is a $I(1)$ process. Mixed cointegration test results were obtained from the Johansen test and Phillips-Ouliaris test (Johansen, 1990, Phillips and Ouliaris, 1990). While the former test failed to reject the null hypothesis of no cointegration, the latter test rejected the no-cointegration null. The results from estimating the vector autoregression correction model (VECM), however, lends support to the inference that the three variables have one cointegration relationship.⁸ Thus, we proceed with specification that allows for one cointegration relationship, and report in Table 2 the results of estimating the VECM:

$$\Delta H_t = \alpha_1 + \delta_1 EC_{t-1} + \phi_1 \Delta H_{t-1} + \beta_1 \Delta X_{t-1} + \gamma_1 \Delta F_{t-1} + \varepsilon_{1t}, \quad (2)$$

$$\Delta X_t = \alpha_2 + \delta_2 EC_{t-1} + \phi_2 \Delta H_{t-1} + \beta_2 \Delta X_{t-1} + \gamma_2 \Delta F_{t-1} + \varepsilon_{2t}, \quad (3)$$

and

$$\Delta F_t = \alpha_3 + \delta_3 EC_{t-1} + \phi_3 \Delta H_{t-1} + \beta_3 \Delta X_{t-1} + \gamma_3 \Delta F_{t-1} + \varepsilon_{3t}, \quad (4)$$

where EC_{t-1} is the error correction term⁹, and the lag structure is selected using the information criteria AIC and SC.

The VECM results show that the order flow affects the CNH exchange rate through two channels. One is the empirical long-run channel represented by equilibrium correction via the error correction term. The other one is the short-term channel captured by the lagged order flow. The EC_{t-1} and ΔX_{t-1} effects on CNH exchange rate returns have their expected signs and are statistically significant. The finding reinforces the order flow effect reported earlier, and is supportive of the notion that order flow causes CNH returns.

The order flow appears exogenous to these variables. None of the coefficient estimates under the ΔX_t specification is statistically significant. On the other hand, the interest rate differential responds to the error correction term with the expected sign – a positive deviation from the empirical long run relationship leads to a decrease in the differential which in turn will shrink the error correction term, *ceteris paribus*.

⁸ For brevity, the unit root and cointegration test results are not reported, but available from the authors. Note that, according to the Granger-Engle representation theorem (Engle and Granger, 1987), the significant equilibrium correction in the VECM is indicative of an cointegrated system.

⁹ The error correction term, with the trend and constant included, is given by $H_t - .0012 X_t + .0108 F_t$, and the t-statistics of the two coefficient estimates are, respectively, -1.85 and 2.87.

Despite the error correction specification reveals the long-term and short-term impacts of order flow on the return of CNH exchange rates, the explanatory power as given by the estimate of the adjusted R-squares is quite small. To explore the roles of other possible determinants, we study an augmented version of equation (2):

$$\Delta H_t = \alpha_1 + \delta_1 EC_{t-1} + \phi_1 \Delta H_{t-1} + \beta_1 \Delta X_{t-1} + \gamma_1 \Delta F_{t-1} + \partial Z_t + \varepsilon_{1t}, \quad (5)$$

where the augmented variable Z_t includes currency volatility index, contemporaneous and lagged) limit order imbalances, and contemporaneous order flow. The results of estimating (5) are presented in Table 3.

For comparison purposes, Column (1) repeats the results of the ΔH_t equation from Table 2. Similar to the results in Table 1, the inclusion of the emerging market currency volatility variable improves the adjusted R-squares estimate by about 7% (Column 2). The effect of the limited order imbalance variable appears to come through the contemporaneous channel – the effect of the lagged variable becomes statistically insignificant in the presence of the contemporaneous limited order imbalance. The order flow variable, on the other hand, exerts both contemporaneous and lagged effects on the return of CNH. The lagged effects from order flow can be interpreted as slow learning or over-reaction (e.g. due to illiquidity) depending on the sign of the effect. Most important for the current analysis is that in all the cases where the lagged effect is negative, the sum of the contemporaneous and lagged effect is positive.

In the presence of these additional microstructure variables, the error correction term loses its statistical significance and the other three lagged variables under the VECM specification retain or reinforce their significance. Put all these together, we infer that the order flow equilibrium correction effect on CNH returns in Table 2 is spurious. The order flow effect is likely to work through the short term channel and transmitted via the contemporaneous and lagged order flow variations.

Among the ΔH_t specifications in these three Tables, the specification that incorporates both current and lagged order flow variables yields the largest estimate of adjusted R-squares. The results reinforce the role of flow order in explaining CNH exchange rate movements.

3.2 *Offshore and Onshore Interactions*

The CNH and CNY exchange rates are exchange rates of the same currency RMB. What is the linkage between these two exchange rates? China's capital control policies segregated the

supply and demand conditions in two markets of these two exchange rates, and keep them separated. Even though they are the prices of the same RMB, they could move separately. However, there are reasons to believe that the CNH exchange rate could affect the CNY exchange rate, and vice versa.

In general, the launch of the offshore RMB market in general, and the CNH foreign exchange trading in particular is hailed as a main event in China's process to liberalization its financial sector. The CNH foreign exchange market in principle could help China to gauge the implications for liberalizing the RMB exchange rate. In the absence of tight and direct capital controls, the CNH foreign exchange market attracts participants from different parts of the world and allows market forces to determine the CNH exchange rate. Thus, price discovery is believed to be a key function of the CNH exchange rate.

The practical question is: Does the information revealed by the CNH exchange rate transmit to the CNY exchange rate? Despite the rapid growth of the nascent CNH foreign exchange market, it is still small compared with the on-shore RMB market. More importantly, the CNY exchange rate is anchored to the daily officially determined RMB fixing rate and is only allowed to fluctuate within a defined band around the fixing rate. Even though China does not directly control the CNH rate, she could indirectly influence it through the RMB fixing and other policy measures. The CNH movement may thus take the hints from the CNY exchange rate.

To shed some insight on the interaction of onshore and offshore RMB markets, we study the causal relationship of the CNY and CNH exchange rates. Since the standard unit root tests affirmed that both exchange rate series are $I(1)$ process, the cointegration approach is adopted to investigate the their dynamics.¹⁰

Both the Johansen test and Phillips-Ouliaris test rejected the no-cointegration null and suggested the presence of one cointegration vector in the bivariate system of CNY and CNH exchange rates.¹¹ The estimated cointegrating vector is $(1, -1.0735)$ and the estimate is highly significant with a t-statistic of -27.78 . Thus, the error correction term used in the corresponding bivariate VECM specification is $(Y_t - 1.0735H_t)$, where Y_t is the CNY exchange rate. In passing, it is noted that the estimated cointegrating vector is quite close to $(1, -1)$; indicating that the two

¹⁰ For completeness, we estimated the bivariate $(\Delta H_t, \Delta Y_t)$ vector autoregression specification. For the sample under consideration, there is no cross-exchange rate interaction. The results are available upon request.

¹¹ For brevity, the unit root and cointegration test results are not reported, but available from the authors.

exchange rates tend to move in tandem on average despite some large deviations observed in Figure 1.

Table 4 presents the results of estimating the bivariate (Y_t, H_t) VECM specification:

$$\Delta H_t = \alpha_1 + \delta_1 EC_{t-1} + \phi_{11} \Delta H_{t-1} + \phi_{12} \Delta H_{t-2} + \beta_{11} \Delta Y_{t-1} + \beta_{12} \Delta Y_{t-2} + \varepsilon_{1t}, \quad (6)$$

and

$$\Delta Y_t = \alpha_2 + \delta_2 EC_{t-1} + \phi_{21} \Delta H_{t-1} + \phi_{22} \Delta H_{t-2} + \beta_{21} \Delta Y_{t-1} + \beta_{22} \Delta Y_{t-2} + \varepsilon_{2t}, \quad (7)$$

where the lag structure is determined by information criteria. Recall the error correction term EC_{t-1} is given by $(Y_{t-1} - 1.0735H_{t-1})$.

The CNY and CNH exchange rates display different equilibrium correction mechanisms – the former exchange rate is not statistically affected by the error correction term while the latter is statistically affected. The estimates of individual coefficients of lagged returns indicate that there are some significant cross exchange rate effects. The second lagged CNH return has a marginal positive impact on the CNY return. A similarly cross-rate lagged effect is observed from CHY return on CNH. Nonetheless, the usual Granger causality block exogeneity Wald test indicated the absence of causal relationship between ΔH_t and ΔY_t . Overall, the VECM results point the equilibrium adjustment is mainly borne by the CNH exchange rate and the short-term feedback between the two RMB exchange rates is not very strong.

Similar to the results in Table 2, the explanatory power of the CNH and CNY VECM specifications is quite low. Again, the roles of other possible determinants are investigated using the following augmented specifications:

$$\Delta H_t = \alpha_1 + \delta_1 EC_{t-1} + \phi_{11} \Delta H_{t-1} + \phi_{12} \Delta H_{t-2} + \beta_{11} \Delta Y_{t-1} + \beta_{12} \Delta Y_{t-2} + \partial_1 Z_t + \varepsilon_{1t}, \quad (6)$$

and

$$\Delta Y_t = \alpha_2 + \delta_2 EC_{t-1} + \phi_{21} \Delta H_{t-1} + \phi_{22} \Delta H_{t-2} + \beta_{21} \Delta Y_{t-1} + \beta_{22} \Delta Y_{t-2} + \partial_2 Z_t + \varepsilon_{2t}, \quad (7)$$

where Z_t include the extra explanatory variables. In addition to the microstructure and macroeconomic variables, we examine the impacts of the official RMB central parity rate on the CNH and CNY exchange rate dynamics. Specifically, we consider a) the change in the log of the central parity rate, ΔP_t , and b) the deviations from the central parity rate, $(P_t - H_{t-1})$ and $(P_t - Y_{t-1})$. The time subscripts used to construct the deviation variables is due to the fact that the central parity rate is announced before the trading in the morning and the CNH and CNY rates are end-of-the-day quotes. That is, the deviation variables capture the information reached the market between yesterday's closing and today's opening.

The results of estimating (6) and (7) are presented in Table 5. To facilitate discussions, we repeated the generic VECM results under Column (1). The basic VECM results are qualitatively the same in the presence of these additional variables. Specifically, it is the CNH return and not the CNY return variable that reacts to the error correction term. The cross-rate effects are similar to those revealed under the VECM setting.

The additional variables have differential abilities to explain variations in returns on CNY and CNH. The marginal explanatory power of the emerging market currency volatility variable, for instance, is again about 7% for the return on CNH but is only about 1% for the CNY return. The limited effect on the CNY reflects this exchange rate is less subject to market influences. The interest rate differential again has no significant impact on either exchange rate.

Apparently, the CNH order flow affects both CNH and CNY exchange rates. The effect on returns on CNH is qualitative similar to the one revealed in Table 4 – both the lagged and contemporaneous order flow variables are significant and have contributed a noticeable improvement in the model performance. For the CNY exchange rate, only the contemporaneous CNH order flow is statistically significant and its presence increases the estimate of adjusted R-squares by only 1%.

The CNH limited order imbalance displays a relatively weak explanatory power. It does not have a significant impact on CNY exchange rates and, in the CNH case, yields a marginal increase of 1% in the adjusted R-squares.

Thus, among the two CNH related microstructure variables, it is the order flow that has implications for the CNY exchange rate. Because the two markets are separated by China's capital control policies, the impact of these microstructure variables is stronger on the CNH than on the CNY.

The official RMB central parity rate has substantial influences on both the CNH and CNY even though its effects work through different variables. In the case of CNY, the exchange rate return responds quite strongly to the change in the central parity rate. At the risk of repetition, we note that the central parity rate is announcement before the morning trading session and the exchange rate return is based on end-of-the-day quotes. Our estimates suggest that, over the average, the change in the central parity rate accounts for slightly more than one half of the change in the CNY exchange rate. The inclusion of the change in central parity rate leads to a big jump in the estimate of the adjusted R-squares – from 6% under Column (7) to 28% under

Column (8). The deviation from the central parity rate also affects the CNY but to a smaller extent – the improvement in the estimate of the adjusted R-squares is about 1%.

The CNH exchange rate, on the other hand, appears to be better explained by its deviation from the central parity rate than the change in the central parity rate. The change in the central parity rate yields a 2% increase while the deviation from the central parity rate yields an additional 11% in the estimate of the adjusted R-squares. The response pattern is different from that of the CNY exchange rate. One possible reason is that the CNH is not subject to the trading band imposed on CNY and, the extra degree of freedom allows the CNH exchange rate to anticipate and respond to the future RMB exchange rate movement. The deviation from the central parity rate thus contains information about refinement of adjustment to the official rate.

The performance of the augmented models is quite encouraging. For daily exchange rate data, the model could explain up to 29% of the variability of CNY returns and 39% of CNH return movements. The difference in the explanatory apparently is due to the effectiveness of the CNH microstructure variables.

4. Additional Analyses

As discussed in the beginning of the previous section, there are reasons for the CNH exchange rate to affect the CNY one, and vice versa. The results based on the whole sample period tend to support the notion of, on the average, CNY is affecting CNH. It is quite possible that the causal link is not constant and change over time. The market participant's currency choice could depend on the relative strength of the two RMB exchange rates. For instance, if the CNH is stronger than CNY, Chinese importers will find it benefits to use CNH to settle their US dollar obligations. Under turbulent market conditions that trigger risk-off trades, the action is likely to take place first in the CNH, instead of the CNY, foreign exchange market.

To explore these possibilities, we examine the causal relationship between CNY and CNH exchange rates in three subsample periods. These subsamples are: (i) the beginning of the sample period to September 21, 2011, (ii) September 22, 2011 to April 13, 2012; and (iii) April 14, 2012 to the end of our sample period. The September 2011 is chosen as a breaking point because it is the beginning of a quite turbulent period in which the CNH displayed an unusually large discount to the CNY. The April 14, 2012 is attributed to the widening of the official CNY trading band from $\pm 0.5\%$ around the central parity rate to $\pm 1\%$. While these choices may appear

somewhat arbitrary, the results shed some light on the variability of the interconnectedness of the two exchange rates. The results pertaining to the coefficient estimates of the error correction term and their level of significance are summarized in Table 6A and to the analysis of short-run Granger causality is presented in Table 6B.

In all three subsamples the CNH exchange rate displays the strongest attraction to the empirical long-run equilibrium term. The lagged error correction term is significant in the three ΔH equations; indicating that the CNH exchange rate is responding to the deviation from the empirical long-run relationship. For the ΔY equations, the error correction term is only statistically significant in the second subsample, which includes a period inflicted by hectic market conditions.

The cross-exchange-rate effect varies across these three subsamples. The estimates of the coefficients of lagged ΔH 's and ΔY 's indicates that a) lagged ΔY 's tend to affect the CNH exchange rate though the effect seems weakened a bit in the third subsample period, and b) the CNY exchange rate is affected by lagged ΔH 's only in the third subsample period. The causal relationship between these two return series is formally tested, and the results are presented in Table 6b. The causality test results are in line with observations based on coefficient estimates. Specifically, in the early periods, the causality runs from the change in the CNY exchange rate to the CNH exchange rate. Towards the end of our sample period, the empirical causal relationship runs from the CNH foreign exchange market to the CNY market. While the causality test results give information on the timing of events and, not necessary, a measure of economic causality, they are suggestive of the way how the two markets respond to each other over these subsample periods.

Given the apparent arbitrariness of the choices of these subsample, we now consider the rolling “regression” analysis to shed further insight on the causality pattern. Figure 3 plots the error correction coefficient estimates together with their t-statistics from the rolling estimation of the VECM. The rolling sample size is 100 observations.

The rolling regression results affirm that the pattern of equilibrium corrections of the CNY and CNH exchange rates tend to vary over time (Figure 3). While the CNY exchange rate tends to respond to the estimated error correction term in the second and three quarters of 2012 and in the later part of the sample period, the error correction term is usually significant in the case of the CNH exchange rate.

The p -values of the block exogeneity test of causality are graphed in Figure 4. Again, the variations in the causation feedback between the returns on the two exchange rates are quite apparent. The causal effect of ΔH on ΔY is more prominent in 2013 than other years, and the effect of ΔY on ΔH appears weakened over the sample period.

In sum, the rolling regression analysis reinforces the subsample exercise; even though the CNY has, on the average, a net effect on CNH, we should not overlook the changes in the lead and lag relationship between these two exchange rates of the RMB.

Another final way to gauge the interconnectedness of the two markets and the implication for the official RMB exchange rate is to examine the out-of-sample forecasting performance of the CNY and CNH exchange rates, and the order flow variable. Specifically, we generate the one-step ahead forecasts from the rolling regression

$$\Delta P_t = \alpha + \beta W_{t-1} + \varepsilon_t, \quad (8)$$

where ΔP is the change in the central parity rate, and the predictor W_{t-1} can be either (i) the return on the CNH exchange rate, ΔH , (ii) the return on the CNY exchange rate, ΔY , or (iii) the CNH order flow, ΔX . The forecast performance of the three predictors, relative to that of a random walk with a drift is presented in Table 7. In passing, we note that a pure random walk without drift performs even worse and is, thus, not discussed for brevity.

The onshore exchange rate ΔY forecasts worse than the offshore market variables, ΔH and ΔX , and yields the largest root mean squared prediction error (RMSE) and mean absolute prediction error (MAE) among these three predictors. The order flow variable gives the smallest forecast error measures. The Diebold-Mariano test, indeed, shows that the forecast performance of the two offshore variables is significantly better than the random walk with drift specification. The results attest the relevance of the information content of these offshore variables on the official RMB exchange rate represented by its official central parity rate.

5. Concluding Remarks

During the process of internationalizing the RMB, the market has created a second exchange rate for the currency. Over the past few years, the CNH exchange rate has attracted increasing interest from market participants, policymakers, and academics. In the current study, we find that the microstructure approach offers a good framework to describe the recently formed CNH exchange rate. The explanatory power of the CNH order flow variable, for

example, is quite comparable to existing microstructure studies on exchange rates (King, et al., 2013). In addition the contemporaneous effect, the order flow has lagged effect on the return of CNH exchange rate. The limit order imbalance, another microstructure variable, also exhibits the expected effects.

Interestingly, these microstructure variables also affect the variations in the CNY exchange rate, albeit their effects are weak. Attesting to the fact that the RMB exchange is heavily affect by policy measures, we found both CNH and CNY exchange rates are affected by their deviations from the official central parity rate, and the change in the central parity rate itself.

On the interaction between the onshore CNY exchange rate and the offshore CNH exchange rate, we find that on the average the latter but not the former exchange rate adjusts to deviations from the estimated equilibrium relationship. Subsample results, however, show that the causal relationship between the two exchange rates of the same currency RMB could change over time. The trading conditions in the two segregated markets could vary according to market situations. Our results show that, towards the end of our sample period, the effect of the offshore CNH exchange rate on the onshore rate is stronger, while the effect of the onshore rate on the offshore one is weaker.

The existence of two deliverable exchange rates for a currency is quite special. Under tight capital controls investors may trade the offshore alternative in order to get exposure to the onshore market. Indeed, price discovery is a presumed function of the offshore exchange rate. Our analysis indicates that information embedded in the offshore CNH foreign exchange market may have implications for the (unobserved) market-based RMB exchange rate. Both the return on the CNH exchange rate and the CNH order are found to have predictive power for the official RMB central parity rate. Does it mean that the Chinese authorities take the development in the offshore market into consideration in determining the central parity rate? A further analysis of the inter-market information flow and its potential links to market infrastructures may be warranted.

Data Appendix

Notation:	Variable:	Source:
Y_t	CNY exchange rate	Ecwin
H_t	CNH exchange rate	Ecwin
volat	J.P. Morgan, EM-VXY Currency Volatility Index	Ecwin
F_t	CNH-USD three month interest rate differential	DataStream
ΔX_t	Net order flow/trading volume	Reuters D2000-2*
LOIm	Net Limit book order	Reuters D2000-2*
P_t	The RMB central parity rate	PBoC

* Authors own calculations

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Table 1. The CNH Exchange Rate and Microstructure Variables

	(1)	(2)	(3)	(4)
Constant	-.013 (-1.98)*	-.013 (-2.08)*	-.008 (-1.37)	-.007 (-1.30)
ΔF_t	.039 (1.38)	.018 (.65)	-.019 (-.78)	-.02 (-.82)
ΔH_{t-1}	-.085 (-.76)	-.114 (-1.08)	-.123 (-.95)	-.123 (-.94)
Δvolat		2.196 (3.94)**	2.244 (4.22)**	2.205 (4.15)**
ΔX_t			.095 (5.55)**	.092 (5.45)**
LOIm				.006 (2.11)*
Adj. R2	.01	.08	.20	.21

Note: The table presents the results of estimating $\Delta H_t = \alpha + \beta \Delta X_t + \gamma \Delta F_t + \varepsilon_t$. H, X, and F are defined in the text. Δvolat is the change in the JP Morgan emerging markets currency volatility index, and LOIm is the limit-order imbalance. Adjusted R-squares estimates are provided in the row labeled “Adj. R2.” Robust t-statistics are given in parenthesis underneath coefficient estimates.

Table 2. The VECM of (H_t, X_t, F_t)

	ΔH_t	ΔX_t	ΔF_t
EC _{t-1}	-0.0264 (-3.07)	1.5538 (.74)	-2.0404 (-2.46)
ΔH_{t-1}	-0.0986 (-2.65)	-5.5316 (-.61)	-4.1240 (-1.15)
ΔX_{t-1}	.0004 (2.74)	.0011 (.03)	.0137 (.92)
ΔF_{t-1}	-.0005 (-1.46)	.0864 (1.00)	-.2936 (-8.58)
C	-.0001 (-1.93)	-.0143 (-.91)	.0021 (.34)
Adj. R2	.0283	-.0026	.1006

Note: The table presents the results of estimating the VECM specifications:

$$\Delta H_t = \alpha_1 + \delta_1 EC_{t-1} + \phi_1 \Delta H_{t-1} + \beta_1 \Delta X_{t-1} + \gamma_1 \Delta F_{t-1} + \varepsilon_{1t},$$

$$\Delta X_t = \alpha_2 + \delta_2 EC_{t-1} + \phi_2 \Delta H_{t-1} + \beta_2 \Delta X_{t-1} + \gamma_2 \Delta F_{t-1} + \varepsilon_{2t},$$

and

$$\Delta F_t = \alpha_3 + \delta_3 EC_{t-1} + \phi_3 \Delta H_{t-1} + \beta_3 \Delta X_{t-1} + \gamma_3 \Delta F_{t-1} + \varepsilon_{3t},$$

where the lag structure is determined by information criteria. EC_t is the estimated error correction term, with the trend and constant included, and is given by H_t -.0012 X_t +.0108 F_t, and the robust t-statistics of the two coefficient estimates are, respectively, -1.85 and 2.87. Adjusted R-squares estimates are provided in the row labeled “Adj. R2.” Robust t-statistics are given in parenthesis underneath coefficient estimates.

Table 3. The VECM specification of the CNH exchange rate return: with augmented variables

	(1)	(2)	(3)	(4)	(5)
Constant	-.0001 (-1.96)	-.0001 (-2.08)	-.0001 (-1.16)	-0.0001 (-1.24)	-0.0001 (-1.01)
EC _{t-1}	-.0264 (-3.07)	-.0187 (-2.24)	-.0080 (-1.06)	-0.0073 (-0.98)	-0.0093 (-1.31)
ΔH _{t-1}	-.0986 (-2.65)	-.1215 (-3.37)	-.1141 (-2.96)	-0.1590 (-3.97)	-0.1405 (-3.67)
ΔF _{t-1}	.0004 (2.74)	.0003 (2.02)	.0002 (1.85)	0.0003 (2.19)	0.0003 (2.27)
ΔX _{t-1}	-.0005 (-1.46)	-.0005 (-1.51)	-.0003 (-1.07)	-0.0005 (-1.41)	-0.0007 (-2.26)
Δvolat		.0207 (7.60)	.0219 (9.00)	0.0227 (9.07)	0.0208 (8.69)
LOIm _{t-1}			.0001 (1.76)	0.0000 (0.93)	0.0000 (1.22)
LOIm				0.0001 (2.90)	0.0000 (1.64)
ΔX _t					0.0010 (7.90)
Adj. R2	.03	.10	.12	0.15	0.23

Note: The table presents the results of estimating $\Delta H_t = \alpha_1 + \delta_1 EC_{t-1} + \phi_1 \Delta H_{t-1} + \beta_1 \Delta X_{t-1} + \gamma_1 \Delta F_{t-1} + \partial Z_t + \varepsilon_{1t}$, where Z_t include the change in the JP Morgan emerging markets currency volatility index (Δvolat), contemporaneous and lagged limit order imbalances (LOIm and LOIm(-1)), and contemporaneous order flow (ΔX_t). Adjusted R-squares estimates are provided in the row labeled “Adj. R2.” Robust t-statistics are given in parenthesis underneath coefficient estimates.

Table 4. The VECM of (H_t, Y_t)

	ΔY_t	ΔH_t
EC _{t-1}	.001416 (.15)	.065539 (4.21)
ΔY_{t-1}	-.14084 (-3.47)	.049671 (.73)
ΔY_{t-2}	-.01664 (-.41185)	.121189 (1.79200)
ΔH_{t-1}	.022432 (.93)	-.08021 (-1.98)
ΔH_{t-2}	.039698 (1.66)	-.08132 (-2.03)
Constant	-.00013 (-3.29)	-.00012 (-1.80)
Adj. R2	.013	.037

Note: The table presents the results of estimating the VECM specifications:

$$\Delta H_t = \alpha_1 + \delta_1 EC_{t-1} + \phi_{11} \Delta H_{t-1} + \phi_{12} \Delta H_{t-2} + \beta_{11} \Delta Y_{t-1} + \beta_{12} \Delta Y_{t-2} + \varepsilon_{1t},$$

and

$$\Delta Y_t = \alpha_2 + \delta_2 EC_{t-1} + \phi_{21} \Delta H_{t-1} + \phi_{22} \Delta H_{t-2} + \beta_{21} \Delta Y_{t-1} + \beta_{22} \Delta Y_{t-2} + \varepsilon_{2t},$$

where the lag structure is determined by information criteria. The error correction term EC_{t-1} is given by (Y_{t-1} - 1.0735H_{t-1}), and the robust t-statistic of the estimates is -27.78. Adjusted R-squares estimates are provided in the row labeled "Adj. R2." Robust t-statistics are given in parenthesis underneath coefficient estimates.

Table 5A. The VECM specification of the CNY and CNH exchange rate returns: with augmented variables

	(1)		(2)		(3)		(4)		(5)	
	ΔY_t	ΔH_t	ΔY_t	ΔH_t	ΔY_t	ΔH_t	ΔY_t	ΔH_t	ΔY_t	ΔH_t
Constant	-0.0001 (-3.29)	-0.0001 (-1.80)	-0.0001 (-3.41)	-0.0001 (-1.92)	-0.0001 (-3.41)	-0.0001 (-1.92)	-0.0001 (-3.42)	-0.0001 (-1.92)	-0.0001 (-2.59)	0.0000 (-0.70)
EC _{t-1}	.0014 (.15)	.0655 (4.21)	-0.0036 (-.39)	.0543 (3.61)	-0.0032 (-.35)	.0547 (3.63)	-0.0031 (-.34)	.0545 (3.62)	0.0025 (0.26)	0.0696 (4.86)
ΔY_{t-1}	-0.1408 (-3.47)	.0497 (.73)	-0.1256 (-3.15)	.0839 (1.28)	-0.1240 (-3.10)	.0857 (1.31)	-0.1216 (-3.03)	.0749 (1.14)	-0.0556 (-1.25)	-0.0419 (-0.65)
ΔY_{t-2}	-0.0166 (-.41)	.1212 (1.79)	-0.0191 (-.48)	.1143 (1.75)	-0.0198 (-.50)	.1134 (1.74)	-0.0194 (-.49)	.1117 (1.72)	-0.0239 (-0.53)	0.1187 (1.83)
ΔH_{t-1}	.0224 (.92)	-0.0802 (-1.98)	.0043 (.18)	-0.1208 (-3.06)	.0054 (.22)	-0.1196 (-3.03)	.0083 (.34)	-0.1325 (-3.31)	-0.0009 (-0.03)	-0.1043 (-2.40)
ΔH_{t-2}	.0397 (1.66)	-0.0813 (-2.03)	.0371 (1.57)	-0.0856 (-2.21)	.0378 (1.60)	-0.0847 (-2.19)	.0378 (1.60)	-0.0847 (-2.19)	0.0423 (1.48)	-0.0417 (-1.01)
Δvolat			.0091 (5.58)	.0213 (7.93)	.0090 (5.49)	.0211 (7.85)	.0091 (5.53)	.0206 (7.63)	0.0077 (4.68)	0.0202 (8.53)
ΔF_t					.0002 (.99)	.0002 (.68)	.0002 (1.01)	.0002 (.64)	0.0001 (0.46)	-0.0001 (-0.42)
ΔX_{t-1}							-0.0001 (-.65)	.0003 (1.77)	0.0000 (-0.19)	0.0003 (2.44)
ΔX_t									0.0003 (3.87)	0.0010 (8.04)
Adj. R2	.01	.04	.05	.11	.05	.11	.05	.11	0.06	0.25

Note: The table presents the results of estimating

$$\Delta H_t = \alpha_1 + \delta_1 EC_{t-1} + \phi_{11} \Delta H_{t-1} + \phi_{12} \Delta H_{t-2} + \beta_{11} \Delta Y_{t-1} + \beta_{12} \Delta Y_{t-2} + \partial_1 Z_t + \varepsilon_{1t},$$

and

$$\Delta Y_t = \alpha_2 + \delta_2 EC_{t-1} + \phi_{21} \Delta H_{t-1} + \phi_{22} \Delta H_{t-2} + \beta_{21} \Delta Y_{t-1} + \beta_{22} \Delta Y_{t-2} + \partial_2 Z_t + \varepsilon_{2t},$$

Where the vector Z_t include the change in the JP Morgan emerging markets currency volatility index (Δvolat), the change in the three month CNH-US interest rate differential, contemporaneous and lagged order flow (ΔX_t and ΔX_{t-1}), contemporaneous and lagged limit order imbalances (LOIm and LOIm(-1)), the change in the central parity rate (ΔP_t), and deviations from the central parity rate ($P_t - H_{t-1}$ and $P_t - Y_{t-1}$). Adjusted R-squares estimates are provided in the row labeled "Adj. R2." Robust t-statistics are given in parenthesis underneath coefficient estimates.

Table 5B. The VECM specification of the CNY and CNH exchange rate returns: with augmented variables

	(6)		(7)		(8)		(9)		(10)	
	ΔY_t	ΔH_t	ΔY_t	ΔH_t	ΔY_t	ΔH_t	ΔY_t	ΔH_t	ΔY_t	ΔH_t
Constant	-.0001 (-2.60)	.0000 (-.71)	-.0001 (-2.57)	.0000 (-.66)	-.0001 (-1.42)	.0000 (.25)	.0000 (-.10)	.0003 (5.54)	.0000 (.00)	.0001 (2.31)
EC_{t-1}	.0026 (.26)	.0718 (5.00)	.0029 (.29)	.0726 (5.07)	-.0006 (-.07)	.0682 (4.36)	.0248 (1.65)	.2484 (10.99)	.0158 (1.47)	.1102 (6.32)
ΔY_{t-1}	-.0576 (-1.28)	-.0487 (-.75)	-.0593 (-1.32)	-.0531 (-.82)	-.0890 (-2.16)	-.0737 (-1.10)	-.0985 (-2.39)	-.1416 (-2.28)	-.1020 (-2.49)	-.1068 (-1.62)
ΔY_{t-2}	-.0229 (-.51)	.1180 (1.81)	-.0210 (-.47)	.1230 (1.89)	-.0084 (-.20)	.1598 (2.36)	-.0199 (-.48)	.0785 (1.26)	-.0206 (-.50)	.1287 (1.94)
ΔH_{t-1}	-.0002 (-.01)	-.1068 (-2.44)	.0000 (-.00)	-.1064 (-2.44)	-.0238 (-.85)	-.1312 (-2.86)	-.0170 (-.60)	-.0832 (-1.96)	-.0173 (-.62)	-.1146 (-2.54)
ΔH_{t-2}	.0419 (1.46)	-.0435 (-1.05)	.0413 (1.44)	-.0450 (-1.09)	.0493 (1.86)	-.0510 (-1.17)	.0535 (2.01)	-.0216 (-.54)	.0525 (1.99)	-.0430 (-1.01)
$\Delta volat$	.0076 (4.67)	.0204 (8.59)	.0075 (4.57)	.0200 (8.43)	.0012 (.76)	.0142 (5.65)	.0010 (.68)	.0134 (5.78)	.0013 (.85)	.0146 (5.91)
ΔF_t	.0001 (.49)	-.0001 (-.33)	.0001 (.46)	-.0001 (-.37)	.0001 (.45)	-.0002 (-.51)	.0001 (.47)	-.0001 (-.47)	.0001 (.47)	-.0002 (-.49)
ΔX_{t-1}	-.0000 (-.24)	.000284 (2.05)	.0000 (-.19)	.0003 (2.15)	-.0001 (-1.50)	.0003 (2.13)	-.0001 (-1.59)	.0003 (1.92)	-.0001 (-1.50)	.0003 (2.19)
ΔX_t	.0003 (3.86)	.0010 (8.05)	.0003 (3.62)	.0010 (7.61)	.0004 (4.32)	.0010 (7.53)	.0003 (4.07)	.0009 (7.00)	.0004 (4.25)	.0010 (7.52)
LOIm(-1)	.0000 (.15)	.0001 (1.85)	.0000 (-.02)	.0000 (1.52)	.0000 (-.49)	.0000 (1.08)	.0000 (-.46)	.0000 (1.34)	.0000 (-.33)	.0000 (1.37)
LOIm			.0000 (1.13)	.0001 (2.04)	.0000 (1.75)	.0001 (2.24)	.0000 (1.71)	.0001 (2.22)	.0000 (1.79)	.0001 (2.32)
ΔP_t					.5707 (13.28)	.4197 (5.97)	.5707 (13.32)	.4199 (6.51)	.5671 (13.30)	.4105 (5.96)
$P_t - H_{t-1}$							-.0170 (-2.19)	-.1206 (-10.32)		
$P_t - Y_{t-1}$									-.0230 (-3.19)	-.0585 (-5.04)
Adj. R2	.06	.25	.06	.26	.28	.28	.29	.39	.29	.31

Note: See the Note to Table 5A.

Table 6. The VECM specification of the CNY and CNH exchange rate returns: different subsamples

	September 30, 2010 – September 21, 2011		September 22, 2011 – April 13, 2012		April 14, 2012 – August 27, 2013	
	ΔY_t	ΔH_t	ΔY_t	ΔH_t	ΔY_t	ΔH_t
EC_{t-1}	0.0040 (0.30)	0.069 (2.98)	-0.0939 (-1.60)	0.3083 (2.95)	0.0100 (0.31)	0.1464 (3.71)
ΔY_{t-1}	-0.1403 (-2.03)	0.3250 (2.70)	-0.1295 (-1.36)	-0.5949 (-3.50)	-0.1448 (-2.08)	0.1350 (1.61)
ΔY_{t-2}	-0.0407 (-0.58)	0.0389 (0.32)	0.0078 (0.08)	0.16067 (0.92)	0.0245 (0.37)	0.0776 (0.96)
ΔH_{t-1}	0.0363 (0.92)	-0.0743 (-1.08)	-0.0535 (-1.05)	0.0197 (0.22)	0.1555 (2.81)	-0.0534 (-0.80)
ΔH_{t-2}	0.0395 (1.03)	-0.0649 (-0.97)	0.0490 (0.97)	-0.0574 (-0.63)	-0.0677 (-1.26)	-0.1813 (-2.80)
Constant	-0.0002 (-2.63)	-0.0001 (-1.05)	-0.0001 (-0.88)	-0.0001 (-0.66)	-0.0001 (-2.03)	-0.0001 (-1.72)
Adj. R2	-0.00	0.06	0.05	0.13	0.02	0.07

Note: See the Note to Table 4.

Table 6B. The VECM specification of the CNY and CNH exchange rate returns: p-values from the Granger causality test for different sub-samples

	September 30, 2010 – September 21, 2011	September 22, 2011 – April 13, 2012	April 14, 2012 – August 27, 2013
$\Delta H \not\Rightarrow \Delta Y$	0.439	0.315	0.002
$\Delta Y \not\Rightarrow \Delta H$	0.026	0.001	0.242

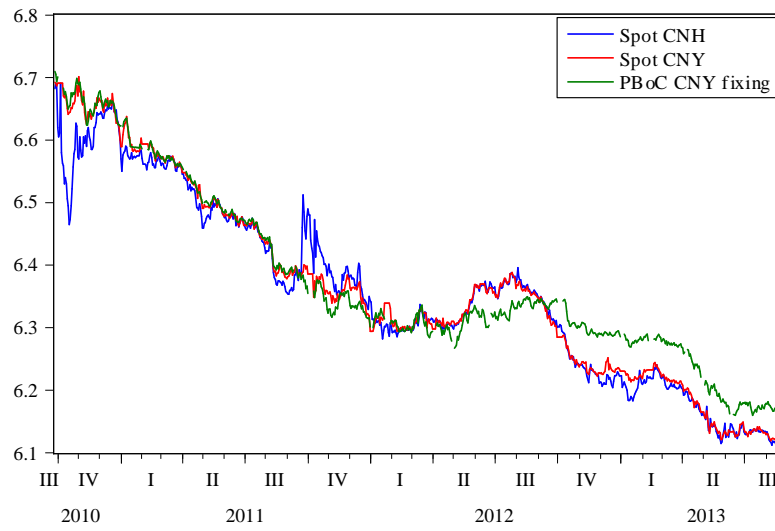
Note: Table presents p-values of the test of excluding lags in the short-run dynamics of the VECM. “ $\Delta H \not\Rightarrow \Delta Y$ ” gives the p-values of testing the null hypothesis of ΔH does not cause ΔY ; that is, the exclusion of lags of ΔH for the specification of ΔY . “ $\Delta Y \not\Rightarrow \Delta H$ ” gives the p-values of testing the null hypothesis of ΔY does not cause ΔH .

Table 7. Out-of-sample forecasting of the change in the RMB central parity rate

	ΔH_{t-1}	ΔY_{t-1}	ΔX_{t-1}	RW
RMSE	0.541 (0.84)	0.547 (-0.27)	0.538 (2.54)	0.546
MAE	0.415 (2.56)	0.427 (0.09)	0.418 (2.77)	0.427

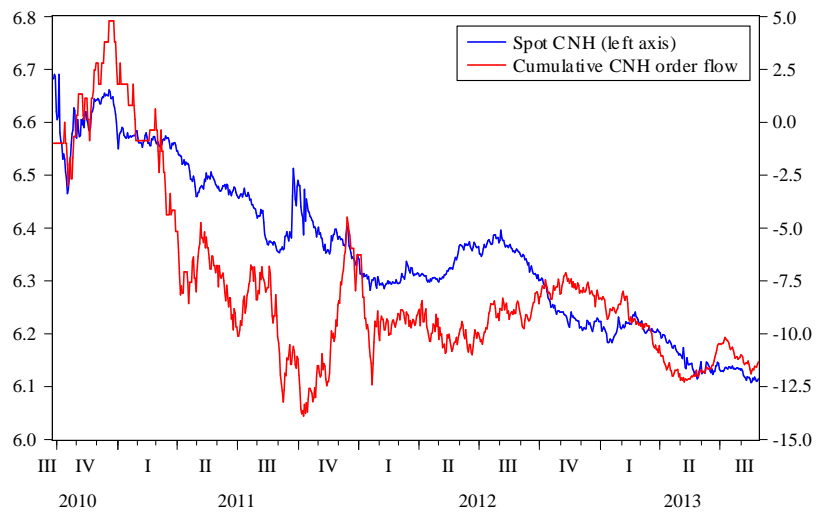
Note: Rows “RMSE” and “MAE” reports the Root Mean Squared prediction Errors and Mean Absolute prediction Errors for differences between the actual RMB central parity rate and the forecast of the central parity rate conditioned on lagged values of ΔH , ΔY , ΔX , or a constant. Numbers in parenthesis are robust Diebold-Mariano t -statistics for testing the significant difference between the random walk forecast and the alternative forecast. A positively significant statistic means the random walk forecast has a larger error.

Figure 1: CNH exchange rate, CNY exchange rate, and the RMB Central Parity Rate



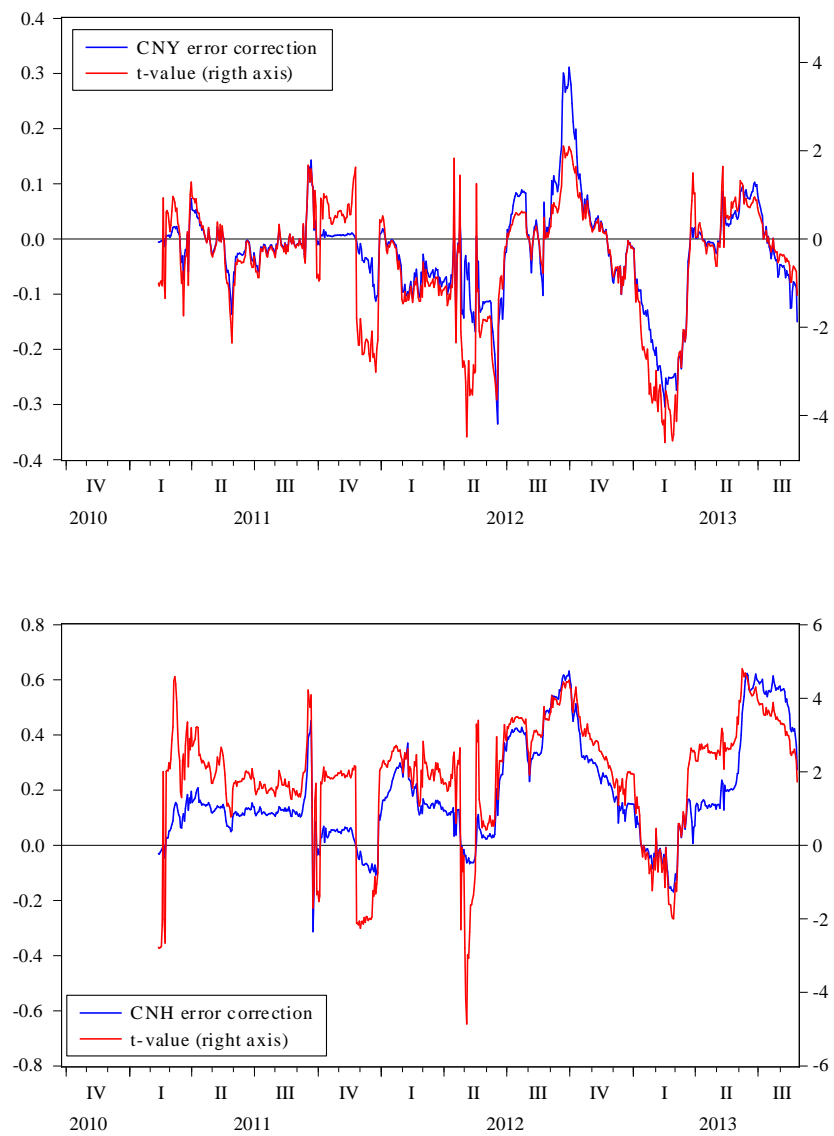
Note: The figure shows the offshore CNH/USD, the onshore CNY/USD and the RMB/USD central parity. The central parity is fixed each morning, while the two other rates are sampled at end of day. Sample: Sept. 27, 2010 — Aug. 27, 2013. Source: PBoC, Ecowin and DataStream.

Figure 2: CNH exchange rate and accumulated CNH order flow



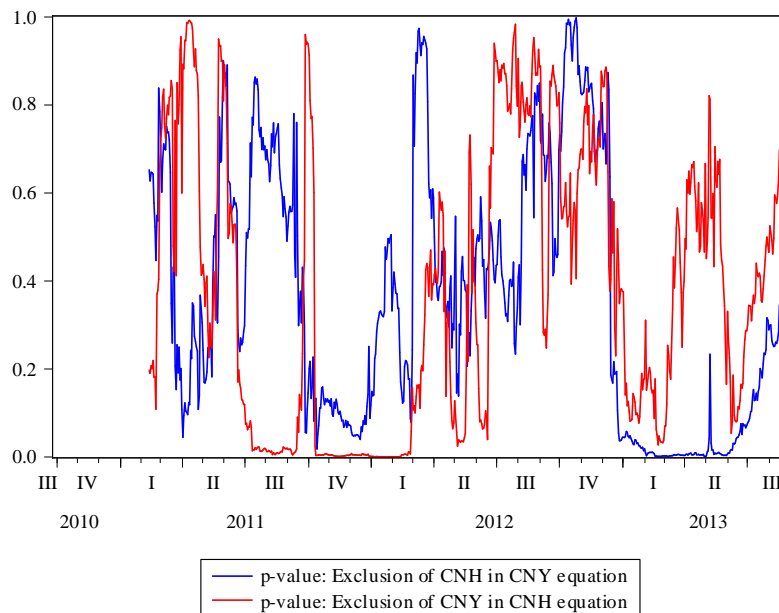
Note: The figure shows the offshore CNH/USD (left axis) and the cumulative normalized CNH/USD order flow. The order flow is created based on tick-by-tick data, and the daily aggregate is then normalized by dividing by daily number of trades. Sample: Sept. 27, 2010 — Aug. 27, 2013. Source: Reuters D2000-2 and Ecowin.

Figure 3: Rolling estimates of error-correction coefficients and their respective t -statistics



Note: The upper panel show the rolling response of the ΔCNY to the lagged deviations from the cointegrating relation (the error correction), together with the t -statistic of the coefficient on the right axis, while the lower panel shows the same for the ΔCNH . The rolling estimate of the VECM is based on 100 observations. Sample: Sept. 27, 2010 — Aug. 27, 2013.

Figure 4: Rolling estimates of p -values for block exogeneity test



Note: The graph show the p -values of a Wald-test for the exclusion of lags of CNY in the equation for CNH, and vice versa. A low p -value mean that one can reject the exclusion of the lags of e.g. CNY in the equation for CNH (and vice versa). The rolling estimate of the VECM is based on 100 observations. Sample: Sept. 27, 2010 — Aug. 27, 2013.