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The Renminbi central parity: An empirical investigation

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Abstract

On August 11, 2015, China revamped its procedure for setting the official central parity of the renminbi (RMB) against the US dollar. Our empirical investigation suggests that the intertemporal dynamics of China's central parity shifted after this policy change, though the deviation of the RMB offshore rate from the central parity and the US dollar index remained the two significant determinants of central parity after the policy change. In contrast, the VIX index only offered explanatory power up to August 2015. Thereafter, the onshore RMB rate and the difference between the one-month offshore and onshore RMB forward points have significant impacts on the central parity. While the US dollar index effect remains, we find no evidence of a rate-fixing role for the RMB exchange rate against the currency basket announced by China in December 2015.

JEL Codes: F31, F33, G15, G17, G18.

Keywords: China, RMB, exchange rate policy, central parity rate, onshore and offshore rates.

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1 Introduction

On August 11, 2015, the People's Bank of China issued a brief statement on improvements to its mechanism for setting the official central parity of the renminbi (RMB) against the US dollar. The central bank claimed that the new formation mechanism would give market forces a greater role in setting the daily official rate, also known as the fixing rate, by referring to the previous day's closing rate of the RMB, market demand and supply, and the valuation of other major currencies (People's Bank of China, 2015). The announcement was not well received. Investors witnessed a 1.9% RMB depreciation on the first day and a cumulative drop of 4.4% over the first three trading days under the new fixing procedure.

The IMF's view that the change was "a welcome step as it should allow market forces to have a greater role in determining the (RMB) exchange rate" did nothing to dispel pessimistic market sentiment (International Monetary Fund, 2015). Repeated reassurances and administrative measures, including reported interventions in the onshore and offshore markets, had no impact on market volatility or restoring confidence. Indeed, the inability of China's monetary authorities to articulate exchange rate policy fueled rumors that new fixing procedure was just a thinly veiled devaluation to revive the weak economy.

Global concerns reflected the culmination of China's recent efforts to promote cross-border use of its currency and the RMB's gradual integration into international financial markets. Investor perceptions of a deliberate RMB devaluation policy were prompted by the combination of China's slowing economic growth and the flat-footed official response to the stock market gyrations of early summer of 2015.

Despite the negative market reception, the IMF executive board in November 2015 reiterated its endorsement of China's endeavors at reforming its exchange rate policy by making the RMB the fifth currency of the Special Drawing Rights (SDR) currency basket.[1] China responded by publishing an RMB exchange rate index and announcing that it would determine the RMB's external value relative to the SDR currency basket rather than the US dollar. Market participants renewed their speculation that the reference to the index was cover to reduce criticism of the RMB's slide against the dollar.

Policy debate over the appropriateness of the RMB's valuation is hardly new. In the early 2000s, when China was running huge trade surpluses and amassing huge foreign exchange reserves, RMB undervaluation and misalignment were popular topics. Empirical studies on RMB misalignment of that period include Cheung, Chinn, and Fujii (2007), Cline (2015), Frankel (2006), Funke

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[1] The other four SDR currencies are the US dollar, euro, British pound, and Japanese yen.

and Rahn (2005), Korhonen and Ritola, (2011), and Schnatz (2011). When China stepped up efforts after the 2007–2008 global financial crisis to promote overseas use of its currency, the global economy eagerly embraced the arrival of the "globalized" RMB.[2] While the RMB was clearly a heavily managed currency, attempts were made to characterize its dynamics and interactions with the offshore market rate.[3]

Against this backdrop, we study the formation mechanism of the RMB central parity against the US dollar. The central parity, i.e. the official fixing rate, is seen by many as a signal of China's foreign exchange rate policy stance. China has revamped the daily fixing mechanism and expanded the trading band around the fixing rate over the past two decades as part of the financial liberalization process. With China's increasing economic power and financial links, market participants constantly look for clues to infer its policy on exchange rate valuation and convertibility. This partly explains why the new fixing procedure triggered such intense reaction and rattled the international financial community.

While China officially indicated that the RMB exchange rate value will be assessed relative to a currency basket,[4] the anecdotal evidence generally suggests that US dollar exchange rate plays a prominent role in determining the RMB's value. Arguments about RMB undervaluation typically involve the notion of a stable, but low-side, US dollar value of the Chinese currency. The RMB's dollar rate or fixing also comes up in media discussions on the implications of a weakening RMB for capital flows and other asset classes. For example, Frankel (2006, 2009), Ma and McCauley (2011), and Sun (2010), show that the RMB has been managed against the US dollar (or that the US dollar had a very large relative weight in determining the RMB value) since the 2005 exchange rate policy reform.

In the following discussion, we present evidence that the behavior of China's central parity after the August 2015 policy change has been more variable and added several new determining factors. Both the deviation of the offshore RMB rate from its onshore central parity and the US dollar index were two significant determinants of the central parity both before and after the policy change. In contrast, the "fear factor" VIX index loses its explanatory power after August 2015. With the announcement of the policy change, the onshore RMB rate has a significant impact on the central parity, the dependence on the US dollar weakens, and variability of the central parity becomes easier

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[2] Some studies on RMB internationalization are Chen and Cheung (2011), Cheung, Ma, and McCauley (2011), Eichengreen and Kawai (2015), Frankel (2012), and Prasad (2016).

[3] See, for example, Cheung and Rime (2014), Chung, Hui, and Li (2012), Ding, Tse, and Williams (2014), Funke et al. (2015), Frankel (2009), Hong Kong Monetary Authority (2016), and Leung and Fu (2014).

[4] Zhou Xiaochuan, governor of China's central bank, stated in a recent interview (Wang, Zhang, and Huo, 2016): "During the reform of the exchange rate regime, we will significantly enhance the reference to a basket of currencies."

to predict. We find no evidence of a role for the RMB exchange rate against the basket of currencies revealed by China in December 2015 in the fixing process.

In the next section, we a) describe the interaction between the central parity, the onshore rate, and the offshore rate of the RMB, b) present statistical evidence on the effects of the onshore and offshore RMB exchange rates on the official daily fixing rate before and after the policy change introduced in August 2015, and c) consider the possible role of the announced RMB currency basket index. Section 3 assesses the roles of selected economic factors in determining and forecasting the RMB fixing. Concluding remarks are offered in Section 4.

2 Interaction of the central parity with onshore and offshore rates

Although China has steadily strengthened the role of market forces in setting its exchange rate policy, it retains a tight grip on the RMB exchange rate. Market participants scrutinize official central parity rates for hints of shifts in the policy stance or inconsistencies in official views on the currency. Officials re-iterate the goal is currency stability. However, if the central parity and the related market rates tell a different story, the market will be flummoxed and rattled.

To what extent is the central parity rate predictable? Since 2005, each refinement of the central parity formation mechanism has referred to “market forces,” the role of the closing rate of the previous day, and a currency basket (People’s Bank of China, 2005, 2010, 2015).[5] What are the *de facto* roles of these factors? Further, the RMB has had an offshore and onshore exchange rate since the second half of 2010. The offshore rate is subject to less intervention, and thus better reflects market information.[6] If these two rates play a role in determining the central parity formation mechanism, what is their relative importance?

2.1 Preliminary discussion

Four variants of the RMB exchange rate are presented in Figure 1.[7] Panel A includes three US dollar rates of the RMB: the central parity rate, the onshore CNY rate, and the offshore CNH rate. Our sample period runs from October 8, 2010 to August 10, 2015. The sample beginning and end points

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[5] Cheung, Hui and Tsang (2016) offer a succinct account of China’s foreign exchange policy.

[6] Anecdotal evidence indicates no interventions in the offshore CNH market before the second half of 2015.

[7] The data used for this figure and in the rest of the article are described in the Appendix. The corresponding descriptive statistics are also provided in the Appendix.

are dictated by the inception of CNH trading and the change in the central parity formation mechanism in 2015. Panel B covers the period of August 17, 2015 to April 15, 2016, when the new central parity formation mechanism is in place. In addition to the three US dollar rates, the CFETS RMB currency basket index is included in Panel B.[8]

The plot of the RMB rates in Panel A and B shows discernably different patterns. We call the first sample the "pre-change period" and the second the "post-change period." Several observations are in order.

First, the central parity rate shows a general appreciation trend until the end of 2013 and then is relatively stable for the rest of the pre-change period. Between 2014 and the first half of 2015, the central parity remains mostly lower than the CNY and CNH market rates, indicating the RMB is weaker than the official fixing rate. In the post-change period, the central parity rate exhibits a general *depreciation* tendency. The depreciation pattern triggers the rising discontent over the apparent weak RMB policy.

Second, the onshore and offshore rates (CNY and CNH) in the pre-change period tend to move in tandem (with a few noticeably large disparities). As a result, their deviations from the central parity rate usually have the same sign. The changes in CNY and CNH are quite closely related with a correlation coefficient of 0.564. The difference between CNH and the central parity is smaller and more volatile on average than the CNY-central-parity difference.

In contrast, the CNH in the post-change period generally indicates a weaker RMB than the CNY, which tracks the central parity quite well. This evidence bolsters the argument that investors overseas bought into the pessimistic view in the offshore market after the 2015 summer turmoil. Unlike the pattern of the pre-change period, the difference between CNH and the central parity after the policy change is larger and more volatile than the CNY-central-parity differential.

Third, of the three dollar rates, the CNH displays the highest level of volatility. The next most volatile is the CNY rate, with the central parity rate the least volatile. In the pre-change period, the standard errors of the percentage changes of CNH, CNY, and the central parity are, respectively, 0.16, 0.11, and 0.08 (Appendix II). The observed volatility differentials reflect the extent to which these rates are managed. These three rates in the post-change period are more variable than in the pre-change period. The high level of variability reflects the heightened level of uncertainty recorded in the post-change market.

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[8] The CFETS methodology is adopted to calculate the CFETS RMB index using raw data from Bloomberg for the sample (December 31, 2014 = 100, reverse scale). An increase in the index indicates RMB appreciation. Because the market experienced unusual turbulence during the rollout of the new fixing mechanism, we exclude the first four business days from our analysis.

Fourth, the CFETS RMB index does not exhibit a readily recognized pattern relative to, say, the central parity rate. The index rate does not track the three RMB rates, with the sample correlation coefficients between the index and the three RMB rates never exceeding 0.15. Since the index gives the RMB value relative to a basket of currencies, its behavior can be quite different from the RMB's dollar exchange rate.

The variability of the CFETS RMB index in the post-change period is lower than that of CNH, but higher than that of the CNY and the central parity.[9] The reference to a basket of currencies does not necessarily yield a RMB valuation that is more stable than a bilateral rate. While it is not inconsistent with the idea that the reference to a basket of currencies does not mean pegging to a basket (Wang, Zhang and Huo, 2016), the difference in variability forces the market to speculate as to the type of exchange rate stability targeted by Chinese officials.

Our preliminary analyses affirm that the dynamic behavior of the central parity rate changed after August 2015. The set of explanatory variables and their estimated coefficient estimated are statistically different before and after the policy change.[10] Thus, we present the estimation results from before and after the policy change separately to facilitate our discussion.

2.2 Pre-change period

To formally examine the effects of onshore and offshore rates on the central parity in the pre-change period, we consider the specifications:

$$\Delta P_t = \alpha + \beta_1(P_{t-1} - Y_{t-1}) + \beta_2\Delta P_{t-1} + \beta_3\Delta Y_{t-1} + \varepsilon_t, \tag{1}$$

$$\Delta P_t = \alpha + \beta_1(P_{t-1} - H_{t-1}) + \beta_2\Delta P_{t-1} + \beta_3\Delta H_{t-1} + \varepsilon_t, \tag{2}$$

where P, Y, and H, respectively, represent the central parity rate, the onshore CNY rate, and the offshore CNH rate in logs.

At the pre-test stage, we found that the three exchange rate series are individually unit root processes and are cointegrated. While the cointegrating coefficient estimates are not exactly unity, the two deviation-from-the-central-parity series, that is, $(P_t - Y_t)$ and $(P_t - H_t)$, are stationary I(0) processes.[11] Thus, the two deviation series can be viewed as restricted cointegrating relationships of (P, Y) and (P, H), respectively.

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[9] In the post-change period, the standard errors of the percentage changes of CNH, CNY, the central parity, and the CFETS RMB index are, respectively, 0.32, 0.18, 0.15, and 0.24 (Appendix II).

[10] These results are available upon request.

[11] For the sake of brevity, these pre-test results are reported in the Appendix.

With these pre-test results, we interpret equation (1) as an error-correction specification of P derived from the bivariate system (P, Y) with a one-lag structure and the restricted error correction term $P_{t-1} – Y_{t-1}$. Specifications with the restricted error correction term are simple and intuitive for accessing the effect of offshore and onshore rates on the central parity. We also conducted the empirical analyses using the estimated error correction terms; the results that are available upon request are qualitatively similar to those presented here.

Equation (2) carries a similar interpretation for the (P, H) bivariate case.

The results of estimating these two equations are presented in Table 1. The central parity, in the presence of the CNY or CNH variables, does not depend on its own history; the ΔP_{t-1} is statistically insignificant in columns I and II of Table 1.[12] In the case of CNY, the coefficient estimates of $P_{t-1} – Y_{t-1}$ and ΔY_{t-1} are, respectively, negative and positive. The negative $P_{t-1} – Y_{t-1}$ effect implies the central parity is gyrating toward the CNY. Further, the central parity variation, as indicated by the positive ΔY_{t-1} effect, follows the direction of CNY. Similarly, $P_{t-1} – H_{t-1}$ and ΔH_{t-1} by themselves give effects similar to those of the CNY variables. That is, individually, CNY and CNH affect the central parity via the empirical long-run error correction link and the short-term channel represented by their changes.

Column III presents the results of estimating the model that includes both CNY and CNH variables:

$$\Delta Pt = \alpha + \beta 1(Pt-1 – Yt-1) + \beta 2(Pt-1 – Ht-1) + \beta 3\Delta Pt-1 + \beta 4\Delta Yt-1 + \beta 5\Delta Ht-1+ \varepsilon t. \qquad (3)$$

In this case, the central parity is significantly affected by variations in the CNH; the other variables are insignificant. Further, specification (3) yields an adjusted R-squares estimate that is smaller than the pure CNH specification (2). A possible cause of these insignificant estimates is the high correlation between $P_t – Y_t$ and $P_t – H_t$ in the pre-change sample. The sample correlation coefficient of these two variables is 0.94. Such high correlation can lead to multicollinearity that weakens the significance of coefficient estimates.

Column IV presents the result of seeking a parsimonious specification. Taking both parameter significance and explanatory power into consideration, the parsimonious specification is given by:

$$\Delta P_t = \alpha + \beta_1(P_{t-1} – H_{t-1}) + \beta_2\Delta H_{t-1}+ \varepsilon_t, \qquad (4)$$

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[12] The time series {ΔP} by itself follows an AR(1) process: $\Delta P_t = -7.24E-05 + 0.067\Delta P_{t-1}$; Adj. $R^2 = 0.004$.

which has two explanatory variables: the change in the CNH, and the CNH's deviation from the central parity. These two variables explain 4.2% of the variation in the central parity. The result underpins the informational role of offshore markets and confirms the relevance of the information content of the offshore RMB rate on the official RMB central parity.

We note in passing that the one-lag specification is supported by the absence of significant serial correlation in the estimated residuals, and the parsimonious specification in column IV attains the lowest AIC and SIC values.

2.3 Post-change period

In addition to specifications (1) to (3), the behavior of the central parity in the post-change period is studied using:

$$\Delta P_t = \alpha + \beta_1(P_{t-1} - Y_{t-1}) + \beta_2(P_{t-1} - H_{t-1}) + \beta_3\Delta P_{t-1} + \beta_4\Delta Y_{t-1} + \beta_5\Delta H_{t-1} + \beta_6\Delta B_{t-1} + \varepsilon_t, \quad (5)$$

where B is the CFETS RMB index. Note that the index and the bilateral central parity rate do not have the same unit of measurement. (5) is used to study the implications of changes in the index value for variations in the central parity.[13] The estimation results for the post-change period are presented in Table 2.

As in the case of the pre-change period, the central parity does not depend on its own history in Table 2. The ΔP_{t-1} is statistically insignificant in columns I and II.[14]

For equation (1), only ΔY_{t-1} exhibits a statistically significant impact (Column I). The explanatory power, however, is noticeably larger than the corresponding specification in Table 1. The significance and good explanatory power echo the co-movement of the central parity and CNY observed in Panel B of Figure 1. However, the deviation term P-Y is insignificant.

In the case of specification (2), both $P_{t-1} - H_{t-1}$ and ΔH_{t-1} are statistically significant with the expected signs. Even if Panel B of Figure 1 indicates that the offshore rate is quite variable relative to the central parity, the offshore rate still shows a significant impact on the central parity via both the empirical long-term and short-term channels.

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[13] Note that both B and the difference series "P – B" are individually a unit root process. Because of the difference in measurement units, the term "P – B" is not considered.

[14] In the post-change sample, {ΔP} follows an AR(1) process: an AR(1) process: □P_t = 7.24E-05 + 0.210□□P_{t-1}; Adj. R^2 = 0.038. The AR(1) specification has an AR coefficient estimate and an adjusted R-squares estimate larger than the corresponding ones of the pre-change period AR(1) specification reported in footnote 12.

So is this observed CNH effect a spillover phenomenon attributable to a link between CNH and CNY? Probably not. In the post-change period, changes in CNH and CNY have a sample correlation coefficient of 0.43, which is much smaller than the pre-change period value of 0.94.

Column III presents the results of including both CNY and CNH variables. The variables ΔY_{t-1}, $P_{t-1} – H_{t-1}$ and ΔH_{t-1} retain their statistical significance with the expected signs, even if the significance of ΔY_{t-1} is marginal. The evidence indicates that the ability of offshore rates to explain variations in the central parity is beyond the one offered by the onshore rate. However, after the August 2015 policy change, variations in the onshore rate CNY become a relevant factor in explaining the central parity movements.

Despite the hype surrounding the reference to a basket of currencies, column V shows that the CFETS RMB index does not help to explain changes in the central parity. ΔB has a relatively small and statistically insignificant coefficient estimate. When the CFETS RMB index is replace with either the BIS or the SDR RMB index, they also yield an insignificant coefficient estimate.[15] Further if the sample starts on, say, December 14, 2015, i.e. after the publication of the CFETS RMB index, the estimates remain insignificant. For the sake of brevity, these insignificant results are not reported.

It may be hard to compare valuation based on a basket of currencies to that based on a single currency. While it is both practically and theoretically appropriate to assess the value of RMB relative to a currency basket, it is not clear if China intends to anchor its currency to a basket of currencies or use the RMB index to guide its exchange rate policy.

The parsimonious specification for the post-change period, presented under column VI, is given by:

$$\Delta P_t = \alpha + \beta_1(P_{t-1} – H_{t-1}) + \beta_2\Delta Y_{t-1} + \beta_3\Delta H_{t-1} + \varepsilon_t, \tag{6}$$

which includes three significant variables: ΔY_{t-1}, $P_{t-1} – H_{t-1}$, and ΔH_{t-1}.

Here we note two differences between results from the pre- and post-change periods. By comparing the adjusted R-squares estimates in Tables 1 and 2, it is apparent that the central parity becomes easier to model after the change in its formation mechanism. The parsimonious specification, for example, explains 37.3% of the variation in the post-change period (column VI, Table 2), but only 4.2% in the pre-change period (column IV, Table 1). A possible reason for the improved performance is that, by incorporating information about the previous day's closing rate of the RMB into the new central parity formation mechanism, changes in CNH and CNY, which retain a high

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[15] When the CFETS RMB index was introduced, it was reported along with the BIS and SDR RMB indexes. http://www.pbc.gov.cn/english/130721/2988680/index.html.

degree of co-movement in the post-change period (correlation coefficient estimate of 0.546 in the post-change period) have been assigned explicit roles in determining the central parity.

Another difference is that the onshore rate CNY becomes a new factor in explaining the central parity in the post-change period. Before the policy change, the empirical evidence only points to a link between CNH and the central parity. The offshore RMB market is commonly perceived to be a place to garner market intelligence about supply and demand with minimal distortion from official controls. The informational role of CNH is confirmed by its role in explaining the central parity. The results in Table 2 confirm that the role of CNY has strengthened since the introduction the new quotation mechanism of central parity rate. The offshore rate CNH, nevertheless, still aggregates information on overseas supply and demand forces.

3 Economic variables and forecast performance

3.1 US dollar, VIX, and offshore expectations

We use the parsimonious specifications (4) and (6) to evaluate the marginal explanatory power of selected economic variables in the pre-change and post-change periods. Specifically, for data in the pre-change period, we consider the augmented regression:

$$\Delta P_t = \alpha + \beta_1(P_{t-1} - H_{t-1}) + \beta_2\Delta H_{t-1} + \beta_3 Z_{t-1} + \varepsilon_t, \qquad (7)$$

For data in the post-change period the augmented regression:

$$\Delta P_t = \alpha + \beta_1(P_{t-1} - H_{t-1}) + \beta_2\Delta Y_{t-1} + \beta_3\Delta H_{t-1} + \beta_4 Z_{t-1} + \varepsilon_t, \qquad (8)$$

where the variable Z includes other economic factors that affect the central parity. At the pre-test stage, we assess the relevance of several possible factors. Tables 3 and 4, for brevity, report results obtained from variables that yield statistically significant effects.[16]

The three economic variables that offer marginal explanatory power are the US dollar index compiled by the Intercontinental Exchange,[17] the VIX “fear” index, and the difference between the offshore and onshore one month forward points in deliverable forwards.[18] The individual effect of these additional variables is assessed before their combined effect is evaluated.

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[16] The economic variables, including emerging market currencies volatility, A-share index and volatility, A-H share premium, and China’s CDS spread were found to have insignificant effects on the central parity.

[17] The index is a weighted average of the US dollar exchange rates against other major currencies supplied by around 500 banks. The variation of this index is similar to other trade-weighted index such as the Fed’s dollar index and the Wall Street Journal USD index.

[18] A positive CNH-CNY forward-point differential implies the offshore RMB at that future point is expected to be weaker than the onshore RMB. The forward point differential can be considered as a proxy of interest rate differential.

The results in Tables 3 and 4 show the effect of the change in the US dollar index (ΔU_{t-1}) is quite robust across the pre-change and post-change periods. In both sample periods, a stronger US dollar index implies that the Chinese authorities set a stronger US dollar fixing against the RMB. The effect is more distinct in the pre-change period, when the US dollar index has a larger marginal explanatory power over the parsimonious specification in the pre-change period than in the post-change period (Table 3, IV and IVa-i, and Table 4, VI and VIa-i).

The ΔH effect appears unstable in the presence of these economic variables. The US dollar index effect displaces the ΔH_{t-1} effect in the pre-change period. The presence of ΔU_{t-1} renders ΔH_{t-1} statistically insignificance in Table 3. While the ΔH effect in the post-change period remains when the US dollar index is added to the regression, its effect becomes insignificant when a combination of these economic variables is included.

The difference between the central parity and the CNH ($P_{t-1} – H_{t-1}$), nevertheless, retains its significance, i.e. the information relevant for the central parity contained in the change in CNH is dominated by that embedded in the US dollar index. However, the information in $P_{t-1} – H_{t-1}$ is different from the US dollar index.

The VIX effect is mainly detected before the new central parity formation mechanism (Table 3). During the pre-change period, a higher VIX reading implies a weaker RMB fixing. While the original purpose of the S&P 500 volatility index (VIX) was to measure the market's expectations of US equity market volatility, it is today arguably the most widely used indicator of investor risk aversion levels in financial markets. Rey (2013), for example, discusses the use of VIX as an indicator of the global financial cycle and notes the dependence of foreign exchange rates on the global financial cycle.

The "risk-on" and "risk-off" phenomena describe the observation that capital tends toward risky assets when the fear index is low and away when the fear index is high. The studies of Cairns, Ho, and McCauley (2007), Cheung and Rime (2014), and Fatum and Yamamoto (2016) all include the RMB in their studies of the VIX effect for emerging market currencies. Given that the RMB is an emerging market currency, we expect it to be heavily affected by the prevailing market attitude toward risk. The VIX effect reported in Table 3 supports this line of reasoning.

Notably, the VIX does not exert influence on the central parity in the post-change period (Table 4).

The SHIBOR, in contrast, is not a good indicator of onshore market interest rates (which have often been flat over significant periods of time), while the offshore money market occasionally suffers low liquidity and wild fluctuations. According to covered interest parity, the difference between the spot and forward exchange rates (i.e. forward point) is governed by the interest differential between the currencies.

The offshore forward rate, which is more freely traded than its onshore counterpart, is considered a barometer of the market's view on the RMB. We incorporate the difference between offshore and onshore RMB forward points in deliverable forwards to gauge the possible reaction to the discrepancy between the market's assessment and the semi-official view on the near future path of the RMB. Our findings suggest that the discrepancy only displays marginal explanatory power in the post-change period. Specifically, when the offshore forward point suggests a RMB value lower than onshore forward point, the authorities tend to set a stronger RMB fixing against the dollar, i.e. it favors leaning against market expectations.

The result suggests that Chinese officials have sought to improve management of expectations in the offshore market since the policy change in August 2015. Panel B of Figure 1 reveals that the offshore RMB rate is generally weaker than the onshore rate and the central parity. This phenomenon is usually attributed to pessimism in the offshore market caused by uncertainty generated from the currency depreciation after the August 2015 policy change and the initial bungled efforts of the authorities in soothing RMB skeptics. Media reports also noted that China intervened in the offshore market to stabilize the RMB and narrow the gap between the onshore and offshore rates. Thus, the response of the central parity to the offshore view on the future value of the RMB may be part of an effort to reconcile rates in these two markets.

In sum, our results show that, the US dollar's general strength retained its role in determining the central parity after the 2015 policy change. The effect of the CNH variable was weakened in the presence of the US dollar index, i.e. the change in the CNH rate became a non-factor, while the CNH deviation from the central parity continued to play a role. The policy change also modified the role of other variables. In the previous section, we noted that CNY became a factor after the change. In the current section, we found that the VIX effect subsided and the role of offshore expectations emerged in the post-change period.

3.2 Forecast performance

In this subsection, we assess predictability of the central parity. For each model for the pre-change period considered in Table 1 and Table 3 (with models augmented with macro variables), we generate one-step-ahead forecasts from rolling regressions with a moving window of 200 observations. For models of the post-change period in Table 2 and Table 4, a window size of 20 observations is used. The out-of-sample forecast results in pre-change and post-change periods are presented in Table 5 and Table 6, respectively.

Panel A of Table 5 gives the results pertaining to the pre-change period. The model identifiers refer to the column labels in Table 1. The root mean squared forecast error (RMSE), mean absolute forecast error (MAE), and proportion of correct direction of change forecast (DoC) of each model are presented. Results derived from a random walk with drift (RW) specification commonly used as the benchmark in assessing exchange rate forecasting performance are included at the bottom of the panel. The Diebold-Mariano test statistics for testing whether a model's forecasting performance according to one of the three reported measures is better than the RW benchmark appear beneath the individual forecasting measures. A brief description of the Diebold-Mariano test statistic is given in Appendix.

The parsimonious specification with only $P_{t-1} – H_{t-1}$ and ΔH_{t-1} as predicting variables yields the smallest RMSE and MAE. Its MAE is statistically smaller than that of the RW. In other words, the forecasting performance of the parsimonious specification is better than the RW benchmark based on these two criteria. It is also statistically better based on a comparison of mean absolute forecast errors. Model II, which includes the CNH-related variables, also outperforms the RW benchmark with a statistically significant Diebold-Mariano MAE test statistic. In passing, we note that the Model I with only onshore information does poorly. Its forecasting performance based on either RMSE or MAE is worse than the RW benchmark.

The column labelled "DoC" presents the proportion of forecasts that correctly predict the direction of the central parity movement and the Diebold-Mariano test statistic in parentheses underneath the corresponding sample proportion. The statistic tests the hypothesis that the proportion of correct forecasts is ½. When the sample proportion statistic is significantly larger than ½, the forecast is said to have the ability to predict the direction of change. When the statistic is significantly less than ½, we say the forecast tends to give the wrong direction of change.

The three models that include the CNH related variables ($P_{t-1} – H_{t-1}$ and ΔH_{t-1}) correctly predict the direction of change above the ½ threshold. However, the predictive ability cannot be deemed statistically significant. The forecasts from either the RW benchmark or the Model I have less than a one-half chance of predicting the correct direction.[19]

Overall, the evidence suggests that the offshore market offers useful information on the central parity dynamics during the pre-change period. Models that include the change of the offshore RMB rate and the difference between the offshore rate and the central parity, usually generate forecasts better than the random walk benchmark. In several instances, their superior performance is statistically significant.

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[19] The forecasting performance of the AR(1) model given in footnote 12 is worse than the RW benchmark. Its RMSE, MAE, and DoC are 0.481, 0.361, and 0.469, respectively.

The forecasting results from the post-change period offer a different story about the predictive powers of onshore and offshore RMB rates. In Panel B of Table 5, the onshore variables are included in the best performing specification; that is the Model III that gives the smallest RMSE and MAE and the largest DoC measures. The two onshore-rate-related variables, $P_{t-1} – Y_{t-1}$ and ΔY_{t-1}, are included in the three specifications (Models I, III, and V) that outperform that the RW benchmark under the MAE criterion.

All models under consideration have a good chance of correctly predicting the direction of change of the central parity. The proportion of forecasts with the right direction is between 68% and 76%. These sample proportions are statistically well above the 50% mark and larger than the proportion yielded by the RW benchmark. Thus, it is relatively easy here to predict the direction of change of the central parity rate after the formation mechanism introduced in August 2015.

The results in Table 5 reinforce the inference of a shift in the role of the onshore RMB rate in determining the central parity formation process, and the central parity rate is easier to explain and predict after the policy change.[20]

After adding the macro variables, the forecasting performance of the model specifications considered in Tables 3 and 4 are presented in Table 6. Before the policy change, the parsimonious model with three explanatory variables (P – H, ΔU, and ΔVIX) gives the smallest RMSE and MAE numbers that are statistically smaller than the corresponding ones of the RW benchmark (Panel A, Table 6). Comparing the RMSEs and MAEs in the panel, the noticeable improvement in the forecast seems to be attributable to inclusion of the US dollar index variable. The strong link between the US dollar valuation and the setting of the central parity in the pre-change period is well underpinned by the results in this and previous subsections.

The combined Model IVb correctly predicts the direction of change over 70% of the time, and its predictive power is significantly better than flipping a coin. Again, the US dollar index variable is likely the main source of the strong directional predictive ability.

Apart from Model IVa-iii under the RMSE and DoC criteria, all models that include one or more of the three economic variables significantly out-forecast the random walk specification.

Unlike the pre-change period, the inclusion of relevant economic factors to the post-change specifications does not tend to improve their forecasting performance. The best MSAE, MAE, and DoC numbers in Panel B of Table 6 are generated by the parsimonious Model VIc in Table 4. However, the forecasting performance of Model VIc is no better than the best performers of Panel A of

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[20] The forecasting performance of the AR(1) model of ΔP_t for the post-change period again is poor. Its RMSE, MAE, and DoC are 1.077, 0.789, and 0.573, respectively.

the Table 4. Indeed, models incorporating only CNH and CNY variables regularly outperform corresponding models augmented by economic variables. The results highlight the possibility that a better-fitted model specification does not necessarily yield better forecasting results, as well as the fact that evaluations based on regression fit and forecasting can give different results.

4 Concluding remarks

China's financial sector has limited linkage with global financial markets. Nevertheless, it is accelerating its financial integration with the world, and developments in China increasingly affect the global economy. The international repercussions from the change of the People's Bank of China in its central parity formation mechanism are a case in point.

Our preliminary assessment of the shift in intertemporal dynamics of China's central parity after the policy change is that they become more variable, but easier to explain. Delving more deeply, our empirical results show that, while the deviation of the RMB offshore rate CNH and the US dollar index are the two factors that best explain changes in the central parity before and after the policy change, market uncertainty as measured by the VIX "fear factor" index was also a significant explanatory factor between late 2010 and August 2015. After the policy change in August 2015, the RMB onshore rate CNY and the difference between the one-month CNH and CNY forward points emerged as new determinants.

Since the introduction of the managed floating exchange rate regime in 2005, China has reiterated its intention of referencing the RMB exchange rate-setting to a basket of currencies and reflecting actual market supply and demand. The stated objective has been a managed floating arrangement that enhances exchange rate flexibility in response to market forces and emphasizes the stability of the RMB value against a currency basket rather than the US dollar only. The 2015 policy change and the subsequent publication of the CFETS currency basket further signal China's efforts to include the onshore rate and reference to a currency basket in the daily RMB fixing.

Our findings suggest that RMB central parity after the 2015 policy change has been affected by conditions in the offshore and onshore markets as captured by the following: the CNH, the CNY, the value of the US dollar against other major currencies, and the difference between the one-month CNH and CNY forward points.

The significance of the CNY in the post-change period comports with its expanded role highlighted in the August 2015 policy change announcement. The US dollar index effect, which continues into the post-change period, is nevertheless weaker after August 2015. Thus, while the central parity still responds to the general valuation of the US dollar, the link to the US dollar has diminished. Thus, the RMB exchange rate against the US dollar and its stability remain the focus of market participants and the ostensible role of the currency basket index is still insignificant in our analyses.

The difficulty of modeling exchange rates with either a structural approach or a time-series framework is well known. Our empirical settings, nevertheless, reveal possible economic influences on China's central parity formation mechanism. Even before the recent policy change, about a third of the daily central parity variability was attributable to a few exchange rates and economic variables. The central parity was quite predictable. The ability to *explain* the variability and predict changes has been enhanced by the policy change. Thus, the August 2015 policy change, as asserted by the authorities, has increased the level of transparency of the central parity formation mechanism.

An interesting question is the role of the currency basket. Managing a currency basket in an open and transparent way can be tricky for an economy of China's economic power and financial strength. As China's influence on global financial markets is only likely to increase over time, managing a stable level of a currency basket exchange rate could have repercussions for smaller economies with currencies included in such a basket. If the ultimate policy objective is to maintain a stable currency basket exchange rate for the RMB, then the evidence indicates that China is experimenting and exploring ways to maintain stability and to move out of the shadow of the US dollar. During this transition period, China must carefully select the composition and weights of this currency basket to preserve the advantages conferred by its earlier dollar referencing.

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Tables and figures

Table 1 Central parity estimation results (pre-change period)

	I	II	III	IV
$(P_{t-1}-Y_{t-1})$	–0.007		–0.007	
	(–2.989)		(–0.479)	
$(P_{t-1}-H_{t-1})$		–0.005	–1.99E-04	–0.005
		(–2.298)	(–0.016)	(–2.309)
ΔP_{t-1}	0.024	0.017	0.020	
	(0.614)	(0.449)	(0.505)	
ΔY_{t-1}	0.069		–0.009	
	(2.720)		(–0.303)	
ΔH_{t-1}		0.093	0.097	0.095
		(4.769)	(3.965)	(5.099)
Constant	–7.77E-05	–7.43E-05	–7.81E-05	–7.55E-05
	(–3.426)	(–3.331)	(–3.371)	(–3.364)
Adj. R^2	0.016	0.041	0.040	0.042
AIC	–11.487	–11.514	–11.511	–11.515
SIC	–11.470	–11.497	–11.485	–11.502

Note: The table presents the results of estimating (1), (2), (3) and (4) in the text. See the text and Appendix for definitions of variables. Robust t-statistics based on White-Huber (heteroskedasticity) standard errors are given in parenthesis underneath coefficient estimates. Adjusted R-squares estimates are provided in the row labeled "Adj. R^2". The sample period runs from October 8, 2010 to August 10, 2015. Holidays are excluded in the estimation. The lag structure is determined by information criteria.

Table 2 Central parity estimation results (post-change period)

	I	II	III	V	VI
$(P_{t-1}-Y_{t-1})$	–0.103		–0.060	–0.038	
	(–1.088)		(–0.640)	(–0.384)	
$(P_{t-1}-H_{t-1})$		–0.064	–0.047	–0.048	–0.050
		(–3.065)	(–2.256)	(–2.277)	(–2.368)
ΔP_{t-1}	–0.118	0.056	–0.101	–0.106	
	(–1.024)	(0.621)	(–0.977)	(–0.996)	
ΔY_{t-1}	0.467		0.292	0.310	0.258
	(2.457)		(1.517)	(1.510)	(1.776)
ΔH_{t-1}		0.195	0.126	0.127	0.132
		(3.974)	(2.814)	(2.782)	(2.810)
ΔB_{t-1}				–0.037	
				(–0.907)	
Constant	–2.89E-05	–2.82E-04	–2.49E-04	–2.40E-04	–2.18E-04
	(–0.250)	(–1.624)	(–1.525)	(–1.441)	(–1.308)
Adj. R^2	0.293	0.313	0.378	0.377	0.373
AIC	–10.446	–10.476	–10.562	–10.554	–10.567
SIC	–10.369	–10.399	–10.447	–10.420	–10.490

Note: The table presents the results of estimating (1), (2), (3), (5) and (6) in the text. See the text and Appendix for definitions of variables. Robust t-statistics are given in parenthesis underneath coefficient estimates. Adjusted R-squares estimates are provided in the row labeled "Adj. R^2". The sample period runs from August 17, 2015 to April 15, 2016. Holidays are excluded in the estimation. The lag structure is determined by information criteria.

Table 3 Central parity estimation results with augmented variables (pre-change period)

	IV	IVa-i	IVa-ii	IVa-iii	IVb	IVc
$(P_{t-1}-H_{t-1})$	–0.005	–0.004	–0.006	–0.005	–0.004	–0.004
	(–2.309)	(–1.961)	(–2.382)	(–2.311)	(–2.001)	(–2.087)
ΔH_{t-1}	0.095	0.011	0.082	0.095	0.008	
	(5.099)	(0.602)	(4.340)	(5.119)	(0.399)	
ΔU_{t-1}		0.095			0.094	0.094
		(18.951)			(18.731)	(19.876)
ΔVIX_{t-1}			0.002		0.001	0.001
			(4.631)		(1.954)	(2.022)
ΔFP_{t-1}				–0.002	0.002	
				(–0.413)	(0.816)	
Constant	–7.55E-05	–9.69E-05	–7.48E-05	–7.55E-05	–9.63E-05	–9.69E-05
	(–3.364)	(–5.212)	(–3.372)	(–3.366)	(–5.190)	(–5.243)
Adj. R^2	0.042	0.341	0.063	0.041	0.343	0.343
AIC	–11.515	–11.888	–11.536	–11.514	–11.889	–11.892
SIC	–11.502	–11.871	–11.519	–11.497	–11.864	–11.874

Note: The table presents the results of estimating (7) with alternative augmented variables specified in the text. See the text and Appendix for definitions of variables. Robust t-statistics are given in parenthesis underneath coefficient estimates. Adjusted R-squares estimates are provided in the row labeled "Adj. R^2". The sample period runs from October 8, 2010 to August 10, 2015. Holidays are excluded in the estimation. The lag structure is determined by information criteria.

Table 4 Central parity estimation results with augmented variables (post-change period)

Model	VI	VIa-i	VIa-ii	VIa-iii	VIb	Vic
$(P_{t-1}-H_{t-1})$	–0.050	–0.050	–0.052	–0.044	–0.041	–0.051
	(–2.368)	(–2.452)	(–2.506)	(–2.117)	(–2.084)	(–2.514)
ΔH_{t-1}	0.132	0.088	0.134	0.113	0.058	
	(2.810)	(2.313)	(2.896)	(2.125)	(1.274)	
ΔY_{t-1}	0.258	0.261	0.257	0.342	0.358	0.416
	(1.776)	(1.725)	(1.751)	(3.124)	(3.481)	(4.318)
ΔU_{t-1}		0.078			0.088	0.089
		(4.234)			(4.374)	(4.408)
ΔVIX_{t-1}			–0.001		0.001	
			(–0.982)		(0.941)	
ΔFP_{t-1}				–0.020	–0.023	–0.026
				(–1.420)	(–1.666)	(–2.005)
Constant	–2.18E-04	–2.09E-04	–2.30E-04	–1.90E-04	–1.62E-04	–2.19E-04
	(–1.308)	(–1.390)	(–1.380)	(–1.145)	(–1.098)	(–1.466)
Adj. R^2	0.373	0.447	0.372	0.392	0.473	0.466
AIC	–10.567	–10.686	–10.559	–10.591	–10.722	–10.721
SIC	–10.490	–10.590	–10.463	–10.495	–10.588	–10.625

Note: The table presents the results of estimating (8) with alternative augmented variables specified in the text. See the text and Appendix for definitions of variables. Robust t-statistics are given in parenthesis underneath coefficient estimates. Adjusted R-squares estimates are provided in the row labeled “Adj. R^2”. The sample period runs from August 17, 2015 to April 15, 2016. Holidays are excluded in the estimation. The lag structure is determined by information criteria.

Table 5 Forecasting the RMB Central Parity Rate

Panel A: Pre-change period

	RMSE	MAE	DoC
Model IV (Parsimonious model)	0.474 (0.906)	0.348 (3.251)	0.514 (0.885)
Model III (Full model)	0.480 (–0.418)	0.352 (1.494)	0.518 (1.138)
Model II	0.477 (0.138)	0.350 (2.219)	0.516 (1.012)
Model I	0.488 (–1.822)	0.364 (–1.478)	0.476 (–1.518)
RW	0.478	0.359	0.473

Panel B: Post-change period

	RMSE	MAE	DoC
Model VI (Parsimonious model)	1.020 (–0.044)	0.624 (1.800)	0.685 (4.432)
Model V (Full model)	0.761 (2.395)	0.521 (4.004)	0.706 (4.934)
Model III	0.729 (2.731)	0.498 (4.450)	0.755 (6.105)
Model II	0.903 (1.360)	0.672 (1.688)	0.678 (4.265)
Model I	0.903 (1.262)	0.601 (2.757)	0.713 (5.101)
RW	1.011	0.759	0.573

Note: Columns labelled “RMSE”, “MAE”, and “DoC” report the root mean squared prediction errors, mean absolute prediction errors, and direction of changes statistics of the one-step-ahead forecasts of the RMB central parity rate generated by models listed under the first column. The model specifications correspond to those in Table 1 (for the pre-change period, Panel A) and Table 2 (for the post-change period, Panel B). The forecast sample of the pre-change period runs from July 15, 2011 to August 10, 2015 and the post-change period runs from September 15, 2015 to April 15, 2016. The robust Diebold-Mariano t-statistic for testing the model’s forecasting performance relative to a random walk appears in parentheses underneath the RMSE and MAE statistics. A positively significant statistic implies the random walk forecast has a larger forecast error. For DoC, numbers in parentheses are robust Diebold-Mariano t-statistics for testing the hypothesis of the model’s ability to forecast directional change is 0.5. A significantly positive statistic indicates that the forecast can predict the direction of change. See text and Appendix for additional information.

Table 6 Forecasting the RMB Central Parity Rate: with augmented variables

Panel A: Pre-change period

	RMSE	MAE	DoC
Model IVc	0.396 (8.774)	0.266 (14.159)	0.717 (13.724)
Model IVb	0.399 (8.427)	0.270 (13.565)	0.728 (14.420)
Model IVa-iii	0.477 (0.196)	0.350 (2.423)	0.520 (1.265)
Model IVa-ii	0.459 (2.873)	0.335 (4.920)	0.533 (2.087)
Model IVa-i	0.397 (8.385)	0.266 (14.206)	0.719 (13.851)
Model IV (Parsimonious model)	0.474 (0.906)	0.348 (3.251)	0.514 (0.885)
RW	0.478	0.359	0.473

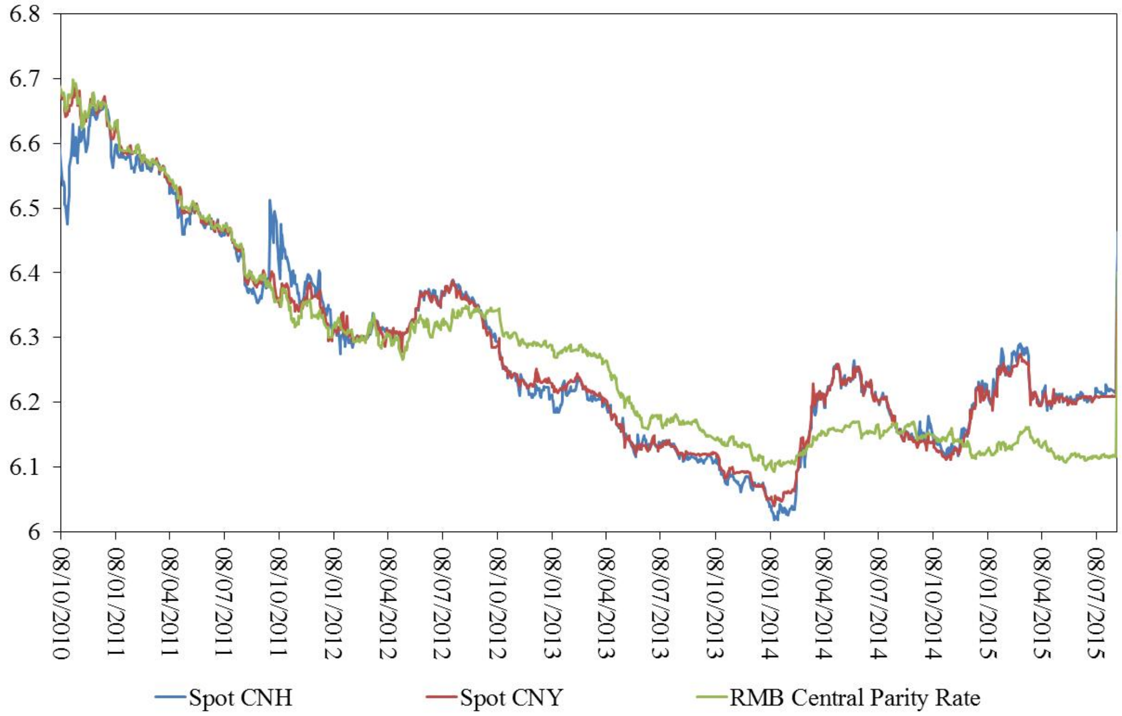
Panel B: Post-change period

	RMSE	MAE	DoC
Model Vic	0.890 (0.717)	0.544 (2.895)	0.734 (5.603)
Model VIb	0.920 (0.586)	0.590 (2.286)	0.678 (4.265)
Model VIa-iii	1.026 (–0.078)	0.651 (1.472)	0.664 (3.930)
Model VIa-ii	0.999 (0.063)	0.631 (1.746)	0.615 (2.760)
Model VIa-i	0.990 (0.098)	0.567 (2.385)	0.734 (5.603)
Model VI (Parsimonious model)	1.020 (–0.044)	0.624 (1.800)	0.685 (4.432)
RW	1.011	0.759	0.573

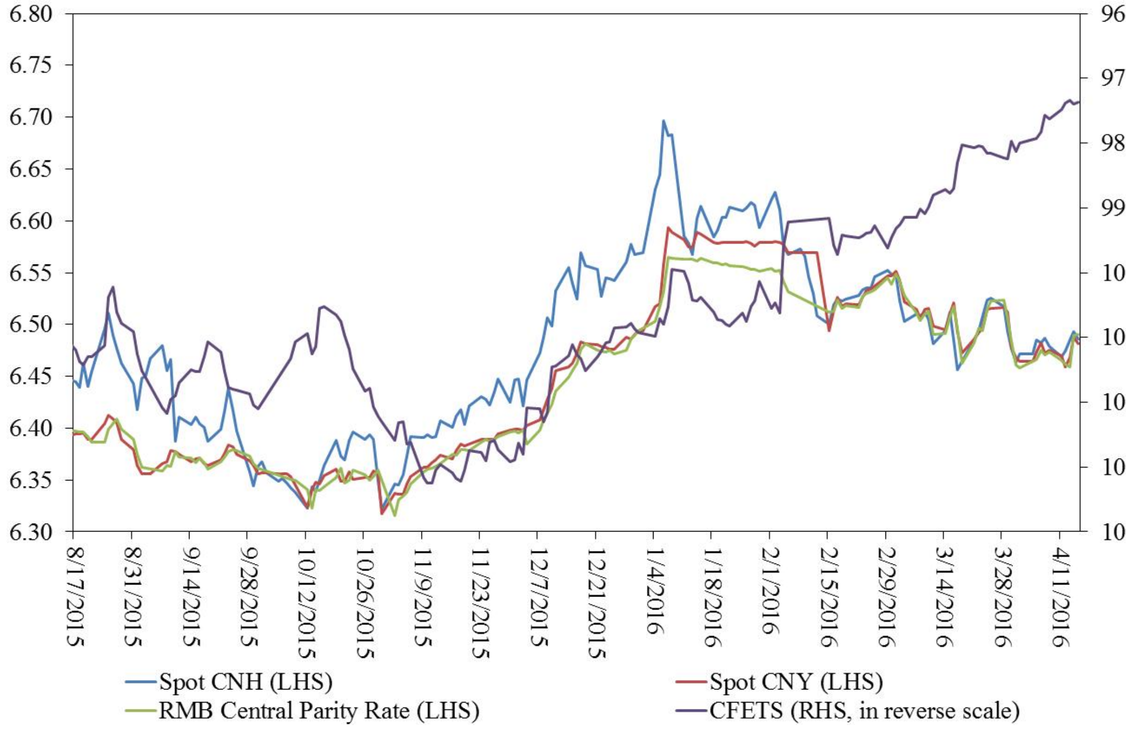
Note: Columns labelled “RMSE”, “MAE”, and “DoC” report the root mean squared prediction errors, mean absolute prediction errors, and direction of changes statistics of the one-step-ahead forecasts of the RMB central parity rate generated by the models listed under the first column. The model specifications correspond to those in Table 3 (for pre-change period, Panel A) and Table 4 (for post-change period, Panel B). See note to Table 5 and text for additional information.

Figure 1 RMB exchange rate.

Panel A: Pre-change period (October 8, 2010 to August 10, 2015)



Panel B: Post-change period (August 17, 2015 to April 15, 2016)



Note: The CFETS RMB index is constructed using the CFETS methodology, December 31, 2014 = 100 (reverse scale). Increases in the CFETS index indicate RMB appreciation relative to the currency basket, while decreases in the RMB Central Parity Rate (P_t), CNH (H_t) and CNY (Y_t) represent the appreciation of RMB relative to the US dollar.

Appendix

I Data definitions and sources

Notation	Variable	Source
P_t	The RMB central parity rate	Bloomberg
Y_t	CNY exchange rate	Bloomberg
H_t	CNH exchange rate	Bloomberg
B_t	CFETS RMB Index	Based on raw data from Bloomberg
U_t	USD index	Bloomberg
VIX_t	VIX index	Bloomberg
FP_t	CNH-CNY 1-month forward-point differential	Bloomberg

II Descriptive statistics and correlations

Descriptive statistics

	Pre-change period October 8, 2010 – August 10, 2015				Post-change period August 17, 2015 – April 15, 2016			
			Serial correlations				Serial correlations	
	Mean	SD	AR(1)	AR(2)	Mean	SD	AR(1)	AR(2)
ΔP_t	–0.0001	0.0008	0.0673	0.0040	0.0001	0.0015	0.2101	–0.0608
ΔY_t	–0.0001	0.0011	–0.0372	–0.0340	0.0001	0.0018	0.1138	–0.0790
ΔH_t	–0.0001	0.0016	–0.0657	0.0102	0.0000	0.0032	0.0139	–0.0273
ΔB_t	--	--	--	--	–0.0002	0.0024	0.1552	–0.1084
(P_t-Y_t)	–0.0009	0.0079	0.9913	0.9846	–0.0009	0.0016	0.5306	0.4440
(P_t-H_t)	–0.0005	0.0092	0.9852	0.9753	–0.0056	0.0057	0.8365	0.7277
(P_t-B_t)	--	--	--	--	–2.7487	0.0247	0.9942	0.9855
ΔU_t	0.0002	0.0048	–0.0306	0.0156	–1.2E-04	0.0057	–0.0436	–0.0662
ΔVIX_t	–0.0006	0.0726	–0.0970	–0.0177	0.0004	0.0963	0.0934	–0.0124
ΔFP_t	1.7E-06	0.0080	–0.3872	–0.0780	–0.0002	0.0129	–0.1711	–0.2940

Correlations

	Pre-change period October 8, 2010 – August 10, 2015	Post-change period August 17, 2015 – April 15, 2016
ΔP_t & ΔY_t	0.420	0.583
ΔP_t & ΔH_t	0.256	0.216
ΔY_t & ΔH_t	0.564	0.546
ΔP_t & ΔB_t	--	0.110
ΔY_t & ΔB_t	--	0.147
ΔH_t & ΔB_t	--	0.114
(P_t-Y_t) & (P_t-H_t)	0.938	0.430
(P_t-Y_t) & (P_t-B_t)	--	–0.188
(P_t-H_t) & (P_t-B_t)	--	0.269
(P_t-H_t) & ΔU_t	–0.064	–0.131
(P_t-H_t) & ΔVIX_t	–0.008	–0.180
(P_t-H_t) & ΔFP_t	0.004	–0.020
ΔH_t & ΔU_t	0.299	0.308
ΔH_t & ΔVIX_t	0.168	0.125
ΔH_t & ΔFP_t	0.039	0.028
ΔY_t & ΔU_t	0.084	0.163
ΔY_t & ΔVIX_t	0.015	0.082
ΔY_t & ΔFP_t	0.223	0.405
ΔU_t & ΔVIX_t	0.222	–0.312
ΔU_t & ΔFP_t	–0.057	0.069
ΔVIX_t & ΔFP_t	–0.052	–0.021

Note: The CFETS RMB index (B_t) is constructed using the CFETS' methodology; December 31, 2014=100 (reverse scale). Higher CFETS index values indicate RMB appreciation relative to the currency basket, while decreases in the RMB Central Parity Rate (P_t), CNH (H_t), and CNY (Y_t) represent appreciation of the RMB against the US Dollar. B_t, P_t, H_t, Y_t, U_t and VIX_t are in logarithm in the table.

III Unit root tests

	Pre-change oe Period October 8, 2010 – August 10, 2015		Post-change Period August 17, 2015 – April 15, 2016	
P_t	–2.200		0.604	
Y_t	–1.505		0.606	
H_t	–1.193		0.128	
B_t	--		–1.677	
$(P_t$-$Y_t)$	–1.855	*	–3.900	**
$(P_t$-$H_t)$	–2.406	**	–4.038	***
$(P_t$-$B_t)$	--		–2.210	
U_t	–1.690		–1.823	
VIX_t	–0.708		–0.163	
FP_t	–3.107		–2.775	

Note: Augmented Dicky-Fuller test statistics for regression specifications selected by AIC are presented. ***, **, and * indicate the rejection of the unit root null hypothesis at the 1%, 5%, and 10% level, respectively.

IV Diebold-Mariano statistics

Diebold-Mariano statistics (Diebold and Mariano, 1995) are used to evaluate the forecast performance of the different model specifications relative to a naive random walk. Given exchange rate series x_t and forecast series y_t, the loss function L for the mean square error is defined as

$$L(y_t) = (y_t - x_t)^2. \tag{A4.1}$$

Testing whether performance of the forecast series different from the naive random walk forecast z_t is equivalent to testing whether the population mean of the loss differential series d_t is zero. The loss differential is defined as

$$d_t = L(y_t) - L(z_t). \tag{A4.2}$$

Under the assumptions of covariance stationarity and short-memory for d_t, the large-sample statistic for the null of equal forecast performance is distributed as a standard normal, and can be expressed as

$$\bar{d} \left\{ \frac{1}{T^2} \sum_{\tau=-(T-1)}^{(T-1)} l\left(\frac{\tau}{S(T)}\right) \sum_{t=|\tau|+1}^{T} (d_t - \bar{d})(d \right. \tag{A4.3}$$

where $l\left(\frac{\tau}{S(T)}\right)$ is the lag window, $S(T)$ is the truncation lag, and T is the number of observations. Different lag-window specifications such as Barlett or quadratic spectral kernels can be applied in combination with a data-dependent lag-selection procedure (Andrews, 1991).

For the direction of change statistic, the loss differential series is defined as follows: d_t takes a value of one if the forecast series correctly predicts the direction of change, otherwise it will take a value of zero. Hence, a value of $\bar{d}$ significantly larger than 0.5 indicates that the forecast can predict the direction of change. On the other hand, if the statistic is significantly less than 0.5, the forecast tends to give the wrong direction of change. In large samples, the studentized version of the test statistic,

$$(\bar{d} - 0.5)/\sqrt{0.25/T}, \tag{A4.4}$$

is distributed as a standard normal.

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