The Exchange Rate System Reform in China: US Pressure, Implicit Gradual Appreciation and Explicit Exchange Rate Bands

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Abstract:

This paper provides a review and empirical investigation of the exchange rate system reform in China over the period between July 2005 and January 2017. We describe the People's Bank of China's (PBoC's) initial achievements and subsequent mistakes in the reform. We note that the central bank's initial honoring of its implicit indication of gradual appreciation played a significant role in its success in the reform initially. However, because of the US pressure for faster renminbi (RMB) appreciation, the PBoC's subsequent violation of the implicit indication of gradual appreciation triggered substantial speculative inflows and hence excessive RMB appreciation and volatility between March 2006 and July 2008. We find that during the first ten years of the reform, the PBoC was actually monitoring the RMB-USD exchange rate instead of the nominal effective exchange rate (NEER). This policy failure was one of the reasons for the substantial drop in China's foreign reserves amid the strengthening of the USD between 2014 and early 2017. The PBoC's mini devaluation on 11 August 2015 was another mistake that had thereafter triggered sharp depreciation and high volatility of the RMB. On the other hand, the several incidences of widening of the RMB-USD exchange rate band over the sampling period was found to have only relatively mild effect on the volatility of the RMB.

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1　Introduction

China's exchange rate system reform since July 2005 is one of the very few, if not the only, successful exit from a fixed exchange rate system without disastrous fluctuations in exchange rates, heavy output losses and substantial economic disturbances. A study of this reform will provide important lessons for policy makers of countries that need to exit from a fixed exchange rate system. It will also enrich the literature in international monetary economics, especially on the choice of exchange rate system and the exit strategy from a fixed exchange rate system.[1] Despite the importance of the reform, however, there has been a lack of in-depth discussion and empirical analysis of it.

This paper studies China's exchange rate system reform, records its policy changes, and investigates its initial success as well as some subsequent mistakes. First, we provide a detail historical account of the changes in the exchange rate system. This includes the background discussion of the effects of the People's Bank of China's (PBoC's) implicit indication of gradual appreciation, its explicit announcements on the width of the exchange rate bands and the US pressure for faster reminbi (RMB) appreciation (i.e., US bashing, as highlighted in McKinnon (2005)). Second, we evaluate empirically the effects of these on the speed of the RMB appreciation/depreciation and the exchange rate volatility. Third, we assess whether the PBoC is following its reform announcement of monitoring the RMB against a basket of currencies, or is still monitoring it against the US dollar (USD). This is an important issue as failure to shift the monitoring target from the RMB-USD exchange rate to the nominal effective exchange rate (NEER) would render China vulnerable to sharp appreciation of the USD such as that between 2014 and early 2017 (see Section 2.2 for the details).[2]

The remaining part of this paper is summarized as follows. In Section 2 we provide a historical account of the exchange rate system reform in China since 2005. We discuss the policy changes of the PBoC and their possible effects on the RMB exchange rate. In Section 3 we outline our

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[1]Along with the debate on the exchange rate system reform, there was also a debate on the choice of exchange rate system for China.

[2]As noted in Yip (2011, p. 124-5), "monitoring" means that the central bank would adjust the exchange rate target if there is a change in the relevant real economic variables or the domestic-foreign inflation differential. However, in the absence of these changes, monitoring NEER means keeping the NEER unchanged, which will automatically help immune the economy against drastic changes in its relative price competitiveness with respect to big nominal swings in major currencies such as the USD or Euro. On the other hand, if the PBoC is monitoring the RMB-USD exchange rate instead of the NEER, a big nominal swing in the USD may cause substantial undesirable change in the economy's relative price competitiveness.

econometric model of the RMB exchange rate, which focuses on the rate of appreciaton/depreciation and volatility in different policy regimes. We report our empirical findings in Section 4 and discuss their implications. Our conclusions are summarized in Section 5.

2 Exchange Rate System Reform and Policy Changes

Before the exchange rate system reform announced on 21 July 2005, economists were debating over a few options of the appropriate reform (see, for example, Goldstein (2004), Eichengreen (2004), Mundell (2004), Zhang (2004) and Frankel (2005)). Yip (2005), who made extensive contributions to this debate over a period of time, pointed out the risks of some of these options.[3] In particular, he highlighted the following:

(a) a once-and-for-all major revaluation, such as the 15-40% revaluation suggested by the US government, would cause serious coordination failure in the economic system, huge output losses and sharp surge in the unemployment rate to politically and socially unbearable levels, and

(b) a medium-size appreciation rate (e.g., 3-5% per annum) or medium-size revaluations (e.g., 3-5% each time) would reward the speculators and hence invite enormous speculative inflows through the illegal channels and the abuse of legal channels, thus creating a severe vicious circle between greater speculative inflows and greater appreciation pressure.[4]

Instead, Yip (2005) recommended engineering, at the initial stage, a very gradual appreciation rate (of, say, 1-2% per annum),[5] with the precondition that speculative inflows would not be rewarded (and hence encouraged) after taking account of the transaction costs and risk premiums of the (illegal) speculative inflows. He also recommended no widening of the exchange rate band

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[3]Yip's proposals were first published in a series of policy articles in the *Hong Kong Economic Journal* between November 2004 and June 2005. These proposals were subsequently collected in Yip (2005).

[4]One possible risk of this vicious circle is a substantial increase in the domestic money supply, which would cause a substantial increase in the share prices, property prices and other asset prices in China. In such case, herding behavior in these asset markets would push the asset prices well beyond the equilibrium levels and create a potential financial crisis or major correction in the future. Yip (2011) argued that the stock market bubble in 2006–7 was at least partly due to the PBoC's wrong choice of a medium-size appreciation rate since mid 2006, which had in turn triggered enormous speculative inflows and hence huge monetary growth and asset inflation pressure.

[5]As noted in Yip (2011), the benefit of a very gradual appreciation was that it could maintain the RMB at the under-valued region for a reasonably long period. The undervalued exchange rate would ensure strong and sustainable economic growth, and avoid significant deterioration of the unemployment rate in the subsequent future. The cost of an undervalued currency was, of course, a less favorable term of trade.

at the initial stage of the reform.[6] Once the gradual appreciation is in place for 1-2 years, China would have already exited from the 8.28 fixed exchange rate system (i.e., 8.28 RMB per USD), and could proceed to the second stage of the reform, which would involve (i) gradually widening the RMB-USD exchange rate band, and (ii) gradually shifting China's exchange rate monitoring target from the RMB-USD exchange rate to the NEER.

2.1 The Initial Reform Announced in July 2005

On 21 July 2005, the PBoC announced its exchange rate system reform with the following key features:

(a) The RMB was revalued against the USD with 2.1% revaluation (i.e., from 8.28 RMB per USD to 8.11 RMB per USD).

(b) The RMB-USD exchange rate would be allowed to fluctuate within a very narrow band of ±0.3% around the closing rate of the previous working day.

(c) The RMB would be monitored against an undisclosed basket of currencies instead of against the USD only.

In parallel to the announcements, there was also an implicit indication that the RMB would thereafter be allowed to appreciate only gradually (i.e., there was an implicit indication of gradual appreciation or stable RMB).[7]

As reported in Yip (2007), the immediate market response to the reform announcement was more moderate than originally expected. On top of the very gradual appreciation with no disruptive changes in output and employment, there were only moderate speculative inflows, which were well within the sterilization capacity of the PBoC. The article also highlighted two important factors that contributed to the initial success of the reform. First, China still had capital control on short-term capital flows. Hence, speculative inflows, whether through illegal channels or abuse of legal channels, were in principle illegal in nature. This implied that there would be non-negligible

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[6]Given the market's belief of a substantial undervaluation of the RMB, a widening of the exchange rate band would only result in lifting the RMB to the upper edge of the band, which would in turn induce more speculative inflows, thus creating greater pressure for appreciation and putting the reform at risk.

[7]As stated in the State Council announcement, the reform has to fulfill the following three principles: "initiated by the Chinese government", "controllable" and "gradual".

transaction costs and risk premiums for the speculative inflows. Second, the implicit indication of gradual appreciation of the RMB had a significant effect on market expectation. By portraying a logically viable reform, the PBoC managed to bring market expectation towards its target path. This had in turn convinced many potential investors that the expected gain from speculating in favour of RMB appreciation could be lower than the associated transaction costs and risk premiums, thus discouraging them from making enormous speculative inflows into China. In the empirical part of this paper, we will investigate the effects of the initial honoring, and the subsequent violation, of this implicit indication of gradual appreciation on the appreciation rate and volatility of the RMB exchange rate over eight identified regimes.

2.2 US Pressure and Subsequent Policy Changes

Although there was some initial success in the reform in that there was no sharp fluctuation in the exchange rate during the first nine months of the reform, it was quite evident that the PBoC slowly deviated from its original implicit commitment of *gradual* appreciation of the RMB amid renewed US pressure for faster appreciation since March 2006.[8] For example, while the appreciation rate was only 1.43% per annum for the first nine months of the reform between 21 July 2005 and 19 March 2006, the appreciation rate accelerated to 3.63% per annum for the next nine months between 20 March 2006 and 20 December 2006, and then further to 5.37% per annum for the subsequent nine months between 21 December 2006 and 20 September 2007. Given the widespread belief that the RMB was substantially undervalued,[9] the faster appreciation, and hence the violation of the implicit commitment of gradual appreciation, triggered further speculative inflows and hence substantial pressure on the monetary growth. These outcomes contributed to a rapid surge in China's share prices and property prices. The rise in these asset prices in turn made speculative inflows more attractive (as there would be both RMB appreciation gain as well as capital gains from share and property investments). By late 2007 and early 2008, there were signs that the speculative inflows and the surge in share prices were almost out of control. For example, as reported in Yip

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[8]On 20 March 2006, there was news that two US Senators would visit China to urge for greater Chinese effort to reduce the undervaluation of the RMB. Since then, the US had been pressurizing China with a potential 27.5% punitive import tariff if China did not make satisfactory progress on this.

[9]As noted in Yip (2007), while there was a debate over whether the RMB was substantially overvalued (see, for example, Cheung *et al* (2007), Frankel (2005), Goldstein (2004), Funke and Rahn (2005), and Chang and Shao (2004)), the market did widely believe the US government's argument that the RMB was undervalued by 15–40%.

(2011), the year-on-year appreciation of the RMB-USD exchange rate reached the peak of 10.8% per annum in May 2008. It also highlighted that China's stock market bubble at that time was at least partially due to the fast appreciation of the RMB, and hence the substantial violation of the implicit indication of gradual appreciation.

Table 1 summarizes a historical account of the PBoC's policy changes amid the US pressure for faster appreciation, the outbreak of the global financial crisis in 2008, the drive for further reforms, and the strong rebound of the USD between 2014 and early 2017. We divide the period of 21 July 2005 to 26 January 2017 into eight regimes/periods. These periods are characterised by either policy changes amid external factors (such as political pressure from the US and the outbreak of the global financial tsunami) or the PBoC's agenda to liberalize. The nine-month period in Regime 1 was very much a period of monitored gradual appreciation of the RMB. Regimes 2 and 3 are characterised by US bashing, whereby pressure was exerted by the US government for faster RMB appreciation. The PBoC succumbed to the pressure, resulting in faster appreciation and diversion from its implicit undertaking of gradual appreciation. In addition, in Regime 3 the PBoC widened the RMB-USD exchange rate band to $\pm 0.5\%$ (PBoC (2007)). In Regime 4, the global financial tsunami kicked in, causing the PBoC to revert to a stable policy stance on the RMB.[10] At the same time the Chinese government launched an ambitious expansionary program. By mid 2010, when the expansionary economic policy seemed to have reaped effect, the PBoC announced the return of the RMB appreciation stance on 21 June 2010 (PBoC (2010)). We characterise this date as the beginning of Regime 5. In Regime 6 the PBoC announced further widening of the exchange rate band to $\pm 1.0\%$ and at the same time occasionally encouraged bidirectional movements of the RMB, while keeping an appreciation stance on it (PBoC (2012)). In Regime 7, the PBoC widened the exchange rate band further to $\pm 2.0\%$ (PBoC (2014)), which was the largest band width since the reform. Together with further encouragement of bidirectional exchange rate movements and the slowly strengthening USD in this period, the PBoC adopted a more neutral stance, resulting in a more neutral period for the RMB.

Finally, Regime 8 started with PBoC's 1.8% devaluation of the RMB-USD exchange rate on 11

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[10]Note that the stable RMB in this regime would not reward speculative inflows and therefore should be counted as no violation of the implicit commitment of gradual appreciation or stable RMB.

August 2015 (PBoC (2015)). The announced devaluation triggered huge capital flight and hence drastic fall in China's foreign reserves and substantial depreciation pressure on the RMB. Such a confidence crisis seemed to be triggered by the devaluation. According to Yip (2016), this crisis was the result of the following mismanagement on the part of the PBoC. First, in the ten years after the reform in July 2005, the PBoC missed the chance of switching its monitoring target from the RMB-USD rate to the NEER. Because of this mistake, market attention was on the RMB-USD rate instead of the NEER. While such a mistake did not cause much problem when the RMB-USD rate was either appreciating or stable over the first seven regimes, the mistake contributed to a confidence crisis when Chinese residents and enterprises interpreted the fall in the RMB-USD rate in this regime as a weaknesss of the RMB instead of a strengthening of the USD.[11] Second, the PBoC's rapid liberalization in the past created significant loopholes, which allowed Chinese residents and enterprises to make the above capital flight through the abuse of legal channels amid the confidence crisis in this period. Third, the PBoC underestimated the negative expectation effect of the devaluation and then the depreciation of the RMB since 11 August 2015, which resulted in a vicious circle of more capital flight, more depletion of China's foreign reserves and further depreciation of the RMB. Fourth, the PBoC allowed the setting up of the RMB currency futures in Hong Kong. This gave speculators opportunities to trigger panic among Chinese residents, which contributed to the capital flight. As a result, there were severe losses in China's foreign reserves due to the capital flight.[12]

Figure 1 presents graphical summary of the RMB-USD exchange rate in the period 21 July 2005 through 26 January 2017. The first panel gives the exchange rate in index form (i.e., USD per RMB, with the exchange rate on 21 July 2005 being 100). The start/end of each regime is marked

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[11]This "interpretation problem" had resulted in a self-fulfilling hypothesis: As shown in Figure 2, the mistake contributed to a substantial fall in China's NEER, which in turn justified the above interpretation made by the Chinese residents and enterprises. On the other hand, as Singapore had been monitoring its NEER instead of the SGD-USD rate since the 1980s and such an commitment had brought enough market attention to Singapore's NEER instead of the SGD-USD rate, there was no confidence crisis in Singapore as the market had interpreted the observed fall in the SGD-USD rate as due to the strong rebound of the USD. Without the confidence crisis and hence enormous capital outflows, Singapore was able to keep its NEER stable, which would mean that appreciation of the Singapore dollar against other currencies would be able to offset the effect of the fall in the SGD-USD rate. This in turn justified the market's interpretation on the strength of the Singapore dollar.

[12]On top of the 1 trillion USD explicit drop in China's foreign reserves between June 2014 and January 2017, the 1.1 trillion USD cumulated current account surplus during that period was used to defend the RMB amid the capital flight (see Yip (2016) for the detailed discussion). Thus, the mistakes had caused at least 2.1 trillion USD explicit and implicit losses in China's foreign reserves between June 2014 and January 2017.

by an asterisk. It is evident that the first three regimes are characterised by the RMB appreciation versus the USD, especially in Regime 3, which has the highest appreciation rate due to pressure from the US. Regime 4 shows a flat period, as a result of the PBoC's choice of a stable stance on the RMB-USD exchange rate amid the global financial tsunami. From Regime 5 onwards the RMB returned to an appreciation path. This directional path took a turn in March 2014, when Regime 7 started. The bidirectional movement of the RMB-USD rate was quite evident in Regime 7. In contrast, Regime 8 showed rapid depreciation, which started from 11 August 2015 when the PBoC announced the devaluation of the RMB versus the USD.

The second panel of Figure 1 plots the differenced logarithmic exchange rate index as daily RMB return. This plot shows clear indication of the volatility of the RMB-USD exchange rate. The volatility increased gradually throughout the first three regimes. The high volatility in Regime 3 was due to the substantial violation of the implicit commitment of gradual RMB appreciation as well as the widening of the exchange rate band. In contrast, when the global financial crisis kicked in, the PBoC reverted to a neutral exchange rate stance so that the RMB-USD exchange rate was steady throughout Regime 4, until the PBoC's announcement on 18 June 2010 to revert to the RMB appreciation path with effect from 21 June 2010. In Regime 5, the return to a moderate violation of the implicit commitment resulted in a rise in the volatility to a much higher level. Thereafter, volatility fell a bit in Regimes 6 and 7, suggesting that the effect of PBoC's choice of lower appreciation rate outdid the effects of PBoC's occasional encouragement of bi-directional movements in the RMB and further widening of the exchange band in the two regimes. In Regime 8, volatility increased substantially. In fact, the volatility was greater than that in Regime 3, suggesting that violation of the implicit commitment in the negative direction had greater effect than a violation of similar size in the positive direction.

3   Econometric Model and Hypotheses

We construct an econometric model of the RMB exchange rate and examine the changes in the estimated model in different regimes defined in Table 1. Let s_t be the logarithmic RMB exchange rate index at time t. As the exchange rate system has 8 regimes, we denote $s_{t,k}$ as the logarithmic

RMB exchange rate index at time t, which falls into the kth regime, for $k = 1, \cdots, 8$.[13] We assume that the conditional mean of $\Delta s_{t,k}$ follows an autoregressive model of order 1, i.e., an AR(1) model, while the conditional variance of $\Delta s_{t,k}$ follows a generalized autoregressive conditional heteroscedasticity model of order $(1, 1)$, i.e., a GARCH(1, 1) model.[14] We allow the intercepts of the conditional mean and conditional variance equations to vary with the regime. This enables us to capture different rates of appreciation and exchange rate volatility in different regimes, in response to changes in PBoC policies. The conditional mean equation is defined as

$$\Delta s_{t,k} = \delta_k + \phi_k \Delta s_{t-1,k} + \varepsilon_{t,k}, \qquad k = 1, \cdots, 8. \tag{1}$$

Given the information set Φ_{t-1} at time $t-1$, the residual $\varepsilon_{t,k}$ is assumed to have conditional variance $\sigma_{t,k}^2$, which follows the GARCH(1, 1) process given by

$$\sigma_{t,k}^2 = \gamma_k + \alpha \varepsilon_{t-1,k}^2 + \beta \sigma_{t-1,k}^2, \qquad k = 1, \cdots, 8. \tag{2}$$

For subsequent exposition we also consider the following alternative formulations:

$$\delta_k = \delta_1 + \sum_{j=2}^{k} \delta_j^*, \qquad k = 2, \cdots, 8, \tag{3}$$

and

$$\gamma_k = \gamma_1 + \sum_{j=2}^{k} \gamma_j^*, \qquad k = 2, \cdots, 8. \tag{4}$$

Thus, δ_j^* and γ_j^* are the incremental changes in the intercept terms of the conditional mean and conditional variance equations, respectively.[15]

We will use our econometric model to examine the effects of PBoC policy changes on the rate of appreciation/depreciation and volatility of the RMB exchange rate index. While initially PBoC announced gradual appreciation of the RMB and a narrow exchange rate band, its stance changed through time due to US bashing, global financial crisis, desire to further liberalize and response to capital flight. Testable hypotheses can be set up to examine the effects of these policy changes.

[13]We also apply the same model to study China's NEER. For exposition purpose, however, we refer to $s_{t,k}$ as the logarithmic RMB-USD index. Note that k is a function of t.

[14]See Bollerslev *et al* (1992) for discussions of econometric models with conditional heteroscedasticity, and Tse and Yip (2003, 2006) for applications of the models to exchange rate systems and interbank markets.

[15]The formulation using $\{\delta_j^*\}$ and $\{\gamma_j^*\}$ is convenient for testing the hypotheses of relative sizes of the intercepts of the conditional mean and conditional variance equations in different regimes using Wald tests. The hypotheses, however, will be stated in terms of δ_j and γ_j, with the index j referring directly to the regimes. In our empirical study, $\{\delta_j^*\}$ and $\{\gamma_j^*\}$ are estimated, and the hypotheses concerning the relative sizes of δ_j and γ_j are reformulated as hypotheses concerning the signs (positive or negative) of various δ^* and γ^*.

Table 2 summarizes a selected set of hypotheses to be tested.[16] The hypotheses are established based on the historical account of the PBoC policy changes outlined in Table 1. We test the changes in the drift of Δs_t (i.e., $\{\delta_j\}$ of the conditional mean equation) and its volatility (i.e., $\{\gamma_j\}$ of the conditional variance equation). Briefly, we hypothesize that US bashing caused the drift to increase from Period 1 to Period 3. It also had the same effect on volatility, which was further reinforced by the widening exchange rate band. Subsequently, the signs of the changes varied through the periods of global financial crisis, return to appreciation stance, as well as the mini crisis in Regime 8.

4 Empirical Results

4.1 Basic Results

We estimate the RMB exchange rate model using quasi-maximum likelihood method. Robust standard errors are computed using White's method (see Wooldridge (2015, Ch 12)). The results for the RMB-USD rate are summarized in Table 3. It can be seen that $\hat{\alpha}$ and $\hat{\beta}$ are both statistically significant, supporting the GARCH(1, 1) formulation. Estimates of ϕ_j are quite small in all periods, supporting the stationarity of Δs_t. The drift and volatility parameters are all significantly different from zero at the 10% level.[17] It can be seen that Period 4 had a significant drop in both the appreciation rate and volatility versus Period 3. Also, there is a significant drop in the appreciation rate in RMB from Period 6 through Period 8 versus the previous period. On the other hand, while there is a significant volatility drop in Period 6 versus Period 5, the drop in the appreciation rate in Period 7 and 8 were accompanied by an increase in volatility. The volatility increase was particularly large in Period 8.

We test the hypotheses in Table 2 using Wald tests (see Wooldridge (2015, Ch 17)). At the 5% level of significance, all alternative hypotheses are significant, except for HD4a, HD8b, HV4b and HV6. Thus, as predicted by the comments in Table 2 the drifts in Period 4 and period 7 are not significantly different from zero (HD4a and HD8b), and the volatilities in Periods 1 and 4 are not significantly different from each other (HV4b). On the other hand, the medium violation of the

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[16]We list hypotheses concerning the drift (appreciation/depreciation) parameters and volatility parameters separately. The hypotheses stated are the alternatives, whereas the null hypotheses are parametric equality.

[17]Note that the significance of $\hat{\delta}_j^*$ and $\hat{\gamma}_j^*$ means that there is significant difference in the drift and volatility versus the previous period, respectively.

gradual appreciation stance in Period 5 versus the substantial violation in Period 3 did not cause significant difference in volatility (HV6).

Table 4 presents estimates of the RMB-USD appreciation rate and volatility over each period parametrically and nonparametrically. Estimates of the appreciation using the parametric AR(1)-GARCH(1, 1) model are given by d_i (over Period i) and d_i^a (annualized over Period i).[18] In contrast, nonparametric estimates of the appreciation rate are given by Δs_{R_i} (over Period i) and $\Delta s_{R_i}^a$ (annualized over Period i). Both sets of estimates show that Period 3 had the highest rate of appreciation, followed by Period 5. On the other hand, Period 8 was the period when the RMB-USD exchange rate dropped most heavily. Parametric and nonparametric estimates of the annualized volatility over each period are presented in the second last and last column, respectively. It can be seen that Period 8 had the highest volatility, followed by Periods 3 and 5.

The third and fourth panel of Figure 1 plot the unconditional parametric estimates of the appreciation/depreciation rate and the volatility in each period, respectively. The bottom panel of Figure 1 plots the GARCH(1, 1) daily (annualized) volatility estimate $\hat{\sigma}_t$. It can be seen that the volatility increased from Period 1 to Period 3, which was caused by the increasing RMB appreciation pressure from US, coupled with the widening of the exchange rate band. The volatility subsided during the global financial crisis in Period 4. From Period 5 to Period 7, volatility broke off from the stable stance in Period 4. In Period 8 we saw a substantial increase in the volatility, which was triggered by the capital flight due to the PBoC's devaluation announcement.

4.2 Economic Implications

In this section, we discuss the economic implications of the estimation results.

4.2.1 Results for Appreciation Rates

The HD1 test in Table 2 supports the hypothesis that the effect of the US pressure on the RMB appreciation in Period 2 results in significantly higher drift than in Period 1 (i.e., $\delta_2 > \delta_1$). The estimated annual drift rate of $d_3^a = 7.4\%$ per annum in Period 3 confirms that there was significant violation of the implicit commitment of gradual appreciation in this period. This estimate is also

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[18]See Notes of Tables 4 and 6 for the computation of these estimates.

substantially higher than that in Regime 2 of $d_2^a = 3.1\%$.[19]

When the PBoC announced a stable policy stance on the RMB amid the global financial tsunami (i.e., Regime 4), the estimated RMB-USD appreciation rates fell drastically to levels that are close to zero. Nevertheless, when the PBoC returned to the appreciation stance after the global financial tsunami (i.e., Regime 5), the estimated RMB-USD drift rate rose to 3.84%, per annum, suggesting that there was once again a moderate violation of the implicit commitment in Regime 5. The test for HD5 in Table 2 confirms that the drift in Regime 5 is significantly greater than that in Regime 4. In Regime 6, the PBoC's occasional encouragement of bidirectional changes in the RMB contributed to a lower appreciation rate of the RMB-USD rate to 2.46% per annum, and the HD7 test confirms that the reduction in the drift rate from Regime 5 to Regime 6 is significant. With the PBoC's more neutral stance amid the strengthening of the USD in Regime 7, the estimated drift rate dropped further to slightly negative values. The test for HD8a confirms that the drop in the appreciation rate from Regime 6 to Regime 7 is significant, and a test for HD8b supports that the drift rate in Regime 7 is not significantly different from zero. Finally, the results in Regime 8 confirm that the PBoC's mistakes discussed in Section 2 had contributed to a substantial depreciation of the RMB-USD rate.[20]

4.2.2 Results for Volatility

Results in Table 4 show that there was a large increase in the volatility of the RMB from 0.663% in Regime 1 to 1.791% in Regime 2.[21] The HV1 test confirms that the difference in the parametric estimates is significant at the 5% level. Thus, the move from the honoring of the implicit commitment in Regime 1 to the moderate violation of the implicit commitment in Regime 2 had caused not only an increase in the appreciation rate, but also an increase in the volatility of the RMB in Regime 2.[22] The result for the HV2 test confirms that the substantial violation of the implicit commitment and the wider exchange rate band (from $\pm 0.3\%$ to $\pm 0.5\%$) in Regime 3 had caused

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[19]Test results are reported at the 5% level of significance. Drift rates d_i^a are annualized.

[20]In fact, a separate plot of China's NEER in Figure 2 (see Section 4.2.3 below) suggests that there was also a sharp depreciation of China's NEER in Regime 8.

[21]We base our discussion on the parametric volatility estimates. The volatilities reported are the annualized standard deviation of returns in percent. See Notes of Tables 4 and 5.

[22]Note that the RMB-USD exchange rate band in Regime 1 and Regime 2 are the same (i.e., $\pm 0.3\%$). Thus, the difference between the two regimes should be due to the US pressure and the moderate violation of the implicit commitment of gradual appreciation in Regime 2.

an increase in the volatility of the RMB. To check whether it was the violation of the implicit commitment or the wider exchange rate band that had contributed the most to the increase in the volatility, we investigate the effect of the two factors on the volatility of the RMB through the following:

(a) Regime 4 versus Regime 2: Despite the wider exchange rate band of $\pm 0.5\%$ in Regime 4 versus $\pm 0.3\%$ in Regime 2, the volatility of 0.666% in Regime 4 is lower than that of 1.791% in Regime 2. The HV4a test confirms that difference is significant, showing that the effect of the moderate violation of the implicit commitment in Regime 2 outdid the effect of the difference in the exchange rate band.

(b) Regime 4 versus Regime 1: As both are regimes with the honoring of the implicit commitment of gradual appreciation or stable RMB, the difference in the volatility in the two regimes would mainly reflect the difference in the width of the exchange rate band. Results in Table 4 show that the estimated volatility of 0.666% in Regime 4 is not much different from the estimated volatility of 0.663% in Regime 1. The HV4b test also shows that the null hypothesis of no difference in the volatility between the two regimes ($\gamma_1 = \gamma_4$) cannot be rejected.

The two comparisons suggest that the effect of the wider exchange rate band on volatility was at most moderate, while the effect of the violation of the implicit commitment on volatility would be relatively large and significant. These also imply that the high volatility in Regime 3 was mainly due to the substantial violation of the implicit commitment instead of the wider exchange rate band.

When the PBoC moved to the moderate violation of the implicit commitment in Regime 5 (from the stable stance in Regime 4) with no change in the width of the exchange rate band, there was once again a sharp increase in the estimated volatility to 2.812% from 0.666% in Regime 4. The HV5 test confirms that the difference in the parametric estimates is significant.

Table 4 also shows that, despite the wider exchange rate band of $\pm 1.0\%$ in Regime 6 versus the $\pm 0.5\%$ in Regime 5 and the PBoC's occasional encouragement of bidirectional movements of the RMB-USD rate, the moderate appreciation in Regime 6 had contributed to a lower volatility of the RMB of 1.534% in Regime 6 versus 2.182% in Regime 5. The HV7 test confirms that the reduction

in the parametric estimate is significant. Nevertheless, with the strengthening of the USD, further widening of the exchange rate band and more PBoC's encouragement of bi-directional movements of the RMB in Regime 7, the volatility increased to 2.108%. The HV8 test confirms that the increase in the volatility is significant.

Finally, the PBoC's mistakes in Regime 8 had triggered a substantial rise in the volatility. In fact, the estimated volatility in Regime 8 is much higher than that in Regime 3, which supports our argument that the effect of a violation of the implicit commitment in the downward direction would be much greater than the effect of a violation of similar size in the upward direction.

4.2.3   PBoC's monitoring target: NEER or the RMB-USD rate?

We now investigate whether the PBoC was monitoring the RMB-USD rate or the NEER. Figure 2 plots the results for China's NEER in the same manner as Figure 1.[23] Table 5 reports the estimation results based on the NEER using the same model as reported in Table 3. As we can see, the log-likelihood of the estimated model is much lower than that of the RMB-USD data in Table 3. On top of this, the PBoC's policy announcements (say, from the appreciation stance in Regimes 1-3 to the neutral stance in Regime 4, and then back to the appreciation stance in Regime 5) were usually expressed in the RMB-USD rate instead of the NEER. More importantly, the behavior of the RMB-USD rate over the eight regimes was more consistent with the PBoC announcements than that of the NEER. For example, the estimates of the annualized RMB-USD appreciation rate in Regime 4 were close to zero and the actual plot of the RMB-USD rate in the first panel of Figure 1 is flat, both of which are consistent with the PBoC's announcement of its stable stance on the RMB. On the other hand, the estimates of the annualized NEER appreciation rate in Regime 4 were substantially different from zero (i.e., -2.24% and -2.64% per annum) and the actual plot of the NEER in Figure 2 is not flat. These results suggest that China's NEER was not the monitoring target of the PBoC.

Overall, we conclude that the PBoC had in the first ten years of the reform failed to shift its monitoring target from the RMB-USD rate to the NEER. This is important as it would make China vulnerable to a substantial appreciation of the USD. In fact, the mini crisis in Regime 8 was partly

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[23]China's NEER index, RMB-NEER15, is the nominal effective exchange rate index compiled by the authors using the trade-weighted average of the bilateral exchange rate indices of the top fifteen trading partners of China.

due to this mistake. Looking forward, even though the PBoC once again indicated in its "mini reform" announcement on 11 August 2015 that it would monitor China's NEER, it seemed that the market discussion and even the PBoC's internal short-term policy target in the first half of 2017 was still on the RMB-USD rate. For example, the market was still talking about whether the RMB would depreciate beyond the psychological support of 7 RMB per USD by the end of 2017 (e.g., see Chen and Orlik (2017) and SCMP (2016)). Parallel to this, the PBoC was working hard to push the RMB-USD rate well above this psychological level so as to ensure that the RMB-USD rate would not fall beyond the psychological level by the end of 2017 or 2018.

5 Summary and Conclusion

In this paper, we argue that the PBoC's implicit indication of gradual appreciation played an important role in the initial success of the exchange rate system reform by guiding the market expectation towards the PBoC's target path. Our empirical results show that the implicit indication contributed to a very moderate appreciation during the first nine months of the reform. This is important as it helped China avoid the mistake of making a once-and-for-all overnight major revaluation, which could cause severe coordination failure in the economic system and hence huge output losses and sharp surge in the unemployment rate to socially and politically unbearable levels.

Despite some reports that the Chinese government managed to smartly alleviate the US pressure for faster appreciation (e.g., Yip (2011, p. 40 and 63)), our empirical results show that there is also evidence that US bashing had contributed to the PBoC's mistake in allowing a moderate violation of the implicit commitment of gradual appreciation in Regime 2. As predicted in Section 2, this mistake had also resulted in a substantial violation of the implicit commitment of gradual appreciation in Regime 3, which was only reverted due to the global financial crisis in Regime 4.

Our empirical results show that the honoring and violation of the implicit indication affect not only the appreciation rate but also the volatility of the RMB. For example, the honoring of the implicit commitment in Regime 1 was accompanied by a relatively low volatility of the RMB when compared with all other regimes that violated the implicit commitment. When China moved to the moderate violation in Regime 2 and the substantial violation in Regime 3, the volatility increased substantially. Thereafter, with the honoring of the implicit indication in Regime 4, volatility falls

drastically from the high levels in Regimes 2 and 3 to a level that is only marginally higher than that of Regime 1. Overall, as the effect of the widening of the exchange rate band on the volatility of the RMB was small, one could argue that this part of the reform was relatively successful because of its careful plan of gradual widening of the exchange rate band. Nevertheless, our empirical results do show that the PBoC had in the first ten years of the reform failed to shift its monitoring target from the RMB-USD rate to the NEER. As explained in Section 2, such a mistake is believed to be one of the underlying reasons for the mini crisis in Regime 8.

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Table 1: Historical account of regime changes in the PBoC exchange rate policy

Period	Event and PBoC Policy	Implication and Observation
1: 21/07/05 - 19/03/06	PBoC followed/honoured its implicit promise of gradual appreciation of RMB.	Appreciation of RMB was gradual in this period (only 1.43% per annum for the RMB-USD exchange rate over the period).
2: 20/03/06 - 17/05/07	US pressurized the Chinese government for faster appreciation of the RMB. Two US senators visited China and threatened a punitive 27.5% import tariff on Chinese exports to US.	PBoC compromised by making faster appreciation of RMB, resulting in violation of the original gradual RMB appreciation policy.
3: 18/05/07 - 16/07/08	Under further US pressure for faster appreciation and free float, PBoC widened the RMB-USD exchange rate band from ±0.3% to ±0.5% on 18/05/07 and allowed even faster appreciation.	There was wider exchange rate fluctuation and a much faster appreciation rate in this period versus Period 2.
4: 17/07/08 - 18/06/10	Chinese export and GDP growth were affected by the global financial tsunami. On 18/07/10 PBoC announced shift to a stable exchange rate stance versus the previous appreciation stance.	While the exchange rate bands in Periods 3 and 4 were the same, there was slower RMB appreciation in Period 4.
5: 21/06/10 - 13/04/12	On 18/06/10 PBoC announced return to the RMB appreciation stance.	RMB appreciation in this period was faster than in Period 4, but slower than in Period 3.
6: 16/04/12 - 16/03/14	On 16/04/12 PBoC announced widening the RMB-USD exchange rate band from ±0.5% to ±1.0%. PBoC also allowed, and occasionally encouraged, bidirectional changes in the RMB exchange rate.	PBoC policy contributed to lower appreciation rate.
7: 17/03/14 - 10/08/15	On 17/04/14 PBoC announced another widening of the RMB-USD exchange rate band from ±1.0% to ±2.0%. PBoC continued to encourage bidirectional changes in the RMB exchange rate. Meanwhile, the strengthening of the USD pressurized PBoC to move back from an appreciation stance to a neutral stance on the RMB exchange rate.	There was higher exchange rate volatility and more bidirectional movements.
8: 11/08/15 - 26/01/17	Drastic fall in Chinas foreign reserves forced PBoC to announce a 1.8% devaluation of the RMB vis-à-vis the USD on 11/08/15, which triggered more capital flight and further depreciation of the RMB.	The capital flight caused substantial depreciation and volatility of the RMB exchange rate.

Table 2: Formulation of Hypotheses

Drift hypothesis	Volatility hypothesis	Comments
HD1: $\delta_2 > \delta_1$	HV1: $\gamma_2 > \gamma_1$	PBoC did not widen the exchange rate band in Period 2. US pressure for RMB appreciation increased both the drift and the volatility in Period 2 versus Period 1.
HD2: $\delta_3 > \delta_2$	HV2: $\gamma_3 > \gamma_2$	In Period 3, US pressure for faster RMB appreciation contributed to increase in both drift rate and volatility. The widening of the exchange rate band also increased the volatility.
HD3: $\delta_3 > \delta_4$	HV3: $\gamma_3 > \gamma_4$	PBoC's shift to a stable exchange rate stance during the global financial crisis in Period 4 contributed to slower appreciation and lower volatility.
HD4a: $\delta_4 > 0$ HD4b: $\delta_4 < \delta_1$	HV4a: $\gamma_2 > \gamma_4$ HV4b: $\gamma_1 < \gamma_4$	The stable exchange rate stance in Period 4 would mean a close to zero appreciation rate (HD4a as alternative hypothesis), which would also be lower than the appreciation rate in Period 1 (HD4b). Both Period 1 and Period 4 are periods with honoring of the implicit commitment of gradual appreciation for RMB. Due to the small difference in the exchange rate bands between Period 1 ($\pm 0.3\%$) and Period 4 ($\pm 0.5\%$), there would be little difference in volatility between the two periods (HV4b as alternative hypothesis). Meanwhile, as there was moderate violation of the implicit commitment in Period 2, volatility in Period 2 may be higher than that in Period 4 (HV4a).
HD5: $\delta_5 > \delta_4$	HV5: $\gamma_5 > \gamma_4$	PBoC's stance in Period 5 for faster appreciation induced higher drift rate and volatility in Period 5 versus Period 4.
HD6: $\delta_3 > \delta_5$	HV6: $\gamma_3 > \gamma_5$	With the same exchange rate band in Periods 3 and 5, the moderate violation of the implicit gradual appreciation in Period 5 versus the substantial violation of the implicit commitment may cause the drift rate and volatility in Period 5 to be lower than those in Period 3.
HD7: $\delta_5 > \delta_6$	HV7: $\gamma_5 > \gamma_6$	The slower appreciation stance in Period 6 versus the moderate violation of implicit commitment in Period 5 would tend to cause a slower appreciation and lower volatility in Period 6. On the other hand, the PBoC's occasional encouragement of bi-directional changes in the RMB-USD exchange rate and the wider exchange rate band in Period 6 may cause higher volatility in this period versus Period 5. HV7 hypothesised that the effect of moderate violation in the implicit gradual appreciation (in Period 5) dominated the effect of the difference in both the explicitly announced exchange rate band and the bi-directional changes in RMB in causing higher volatility in Period 5.
HD8a: $\delta_6 > \delta_7$ HD8b: $\delta_7 > 0$	HV8: $\gamma_7 > \gamma_6$	PBoC's change to a neutral stance in Period 7 from the gradual appreciation stance in Period 6 may cause a slower appreciation than in Period 6. On the other hand, the PBoC's further encouragement of bi-directional changes in the RMB, the wider exchange rate band and the more volatile market sentiment due to the strengthening of the USD in Period 7 may cause higher volatility in Period 7, thus HV8.
HD9: $\delta_8 < 0$	HV9: $\gamma_8 > \gamma_3$	The devaluation on 11/08/15 triggered more capital flight and further depreciation of the RMB. The capital flight and the depreciation of RMB caused higher volatility in Period 8 than in other periods. In fact, the devaluation on 11/08/15 and the followed-up depreciation in Period 8 was a more serious violation of the implicit promise of gradual appreciation than all other periods, including the substantial appreciation in Period 3.

Note: The hypotheses stated above are the alternative hypotheses. For the null hypotheses the inequalities are replaced by equalities.

Table 3: Estimation Results of the AR(1)–GARCH(1, 1) Model for the RMB-USD Exchange Rate

	Coeff ($\times 10^5$)	Std Err ($\times 10^5$)	t-value		Coeff	Std Err	t-value
δ_1	8.6069	3.3692	2.55	ϕ_1	−0.1788	0.0861	−2.08
δ_2^*	5.1261	2.4309	2.11	ϕ_2	−0.1010	0.0489	−2.06
δ_3^*	16.1658	6.7731	2.39	ϕ_3	−0.0173	0.0568	−0.31
δ_4^*	−30.0445	4.5746	−6.57	ϕ_4	−0.0224	0.1187	−0.19
δ_5^*	17.1450	3.6174	4.74	ϕ_5	−0.1144	0.0478	−2.39
δ_6^*	−7.8465	2.6521	−2.96	ϕ_6	0.0640	0.0576	1.11
δ_7^*	−13.4294	3.8394	−3.50	ϕ_7	0.0351	0.0709	0.50
δ_8^*	−36.2908	18.9320	−1.92	ϕ_8	0.0902	0.0512	1.76

	Coeff ($\times 10^8$)	Std Err ($\times 10^8$)	t-value		Coeff	Std Err	t-value
γ_1	3.4460	0.5900	5.84	α	0.4486	0.1194	3.76
γ_2^*	21.6931	4.2139	5.15	β	0.3539	0.0723	4.89
γ_3^*	33.5644	2.3982	14.00				
γ_4^*	−55.2227	5.4957	−10.05				
γ_5^*	58.5063	4.1984	13.94				
γ_6^*	−43.5524	4.2250	−10.31				
γ_7^*	16.3820	3.1079	5.27				
γ_8^*	220.1227	52.7417	4.17				

Notes: Std Err is White's robust standard error. The log-likelihood of the estimated model divided by the number of observations is 6.5235.

Table 4: Estimates of Drift and Volatility of the RMB-USD Exchange Rate

Regime	d_i	d_i^a	Δs_{R_i}	$\Delta s_{R_i}^a$	Parametric volatility	Nonparametric volatility
R_1	1.2558	1.8399	0.9714	1.4232	0.6631	0.4737
R_2	3.7920	3.1433	4.5042	3.7337	1.7909	1.2507
R_3	8.9344	7.4062	11.8551	9.8273	2.7367	2.0207
R_4	−0.0714	−0.0359	−0.1143	−0.0575	0.6664	1.1383
R_5	7.2613	3.8442	7.9742	4.2217	2.8122	1.9189
R_6	4.8891	2.4641	2.6443	1.3327	1.5336	1.2517
R_7	−1.6222	−1.1169	−0.5102	−0.3513	2.1076	1.7918
R_8	−17.0779	−11.2366	−8.4118	−5.5347	5.7031	2.9562

Notes: $d_i = \hat{\delta}_i \times N_{R_i}$ (%), where N_{R_i} is the number of trading days in Regime i. $d_i^a = \hat{\delta}_i \times 252$ (%). Thus, d_i (d_i^a) is the parametric estimate of RMB appreciation (annualized) over Period i. Δs_{R_i} is the logarithmic price at the end of Regime i minus that at the beginning of Regime i. $\Delta s_{R_i}^a = \Delta s_{R_i} \times 252/N_{R_i}$ is the annualized RMB return in Period i. The second last and last column report the estimated annualized volatility in percent, parametrically and nonparametrically, respectively . They are computed as $\sqrt{252\hat{\gamma}_i/(1 - \hat{\alpha} - \hat{\beta})}$ and $\sqrt{252\sum_{t \in R_i}(\Delta s_t)^2/N_{R_i}}$, respectively.

Table 5: Estimation Results of the AR(1)–GARCH(1, 1) Model for the NEER Index

	Coeff ($\times 10^5$)	Std Err ($\times 10^5$)	t-value		Coeff	Std Err	t-value
δ_1	2.1795	0.3257	6.69	ϕ_1	0.0758	0.0741	1.02
δ_2^*	1.2488	0.1901	6.57	ϕ_2	−0.0017	0.0574	−0.03
δ_3^*	21.7109	10.0147	2.17	ϕ_3	−0.1876	0.0605	−3.10
δ_4^*	−16.6497	5.6377	−2.95	ϕ_4	0.0443	0.0523	0.85
δ_5^*	−5.8292	0.5522	−10.56	ϕ_5	−0.0667	0.0525	−1.27
δ_6^*	14.2702	2.4360	5.86	ϕ_6	−0.0443	0.0498	−0.89
δ_7^*	11.2599	2.8480	3.95	ϕ_7	0.0604	0.0650	0.93
δ_8^*	−53.6141	16.6791	−3.21	ϕ_8	0.0335	0.0647	0.52

	Coeff ($\times 10^8$)	Std.Err.($\times 10^8$)	t-value		Coeff	Std.Err.	t-value
γ_1	336.8084	26.0318	12.94	α	0.0858	0.0300	2.86
γ_2^*	−52.1008	4.3069	−12.10	β	0.0799	0.0693	1.15
γ_3^*	36.2961	1.7629	20.59				
γ_4^*	514.2392	15.2119	33.80				
γ_5^*	−313.1286	26.3131	−11.90				
γ_6^*	−225.5466	28.8615	−7.81				
γ_7^*	39.8666	1.9641	20.30				
γ_8^*	136.2514	8.0482	16.93				

Notes: Std Err is White's robust standard error. The log-likelihood of the estimated model divided by the number of observations is 5.6032.

Table 6: Estimates of Drift and Volatility of the NEER Index

Regime	d_i	d_i^a	Δs_{R_i}	$\Delta s_{R_i}^a$	Parametric volatility	Nonparametric volatility
R_1	0.4056	0.5943	0.5992	0.8779	3.1896	3.1025
R_2	1.0404	0.8624	1.6021	1.3281	2.9326	2.8908
R_3	6.4350	5.3342	6.0319	5.0002	3.1139	3.1850
R_4	4.4505	2.2386	5.2462	2.6388	5.0229	5.0650
R_5	1.1871	0.6285	2.1686	1.1481	3.9713	3.9773
R_6	8.1063	4.0856	7.4751	3.7674	2.9930	2.9862
R_7	10.9812	7.5608	10.4131	7.1697	3.1879	3.2353
R_8	−10.0744	−6.6286	−8.9149	−5.8657	3.7787	3.6671

Notes: $d_i = \hat{\delta}_i \times N_{R_i}$ (%), where N_{R_i} is the number of trading days in Regime i. $d_i^a = \hat{\delta}_i \times 252$ (%). Thus, d_i (d_i^a) is the parametric estimate of RMB appreciation (annualized) over Period i. Δs_{R_i} is the logarithmic price at the end of Regime i minus that at the beginning of Regime i. $\Delta s_{R_i}^a = \Delta s_{R_i} \times 252/N_{R_i}$ is the annualized RMB return in Period i. The second last and last column report the estimated annualized volatility in percent, parametrically and nonparametrically, respectively. They are computed as $\sqrt{252\hat{\gamma}_i/(1 - \hat{\alpha} - \hat{\beta})}$ and $\sqrt{252 \sum_{t \in R_i}(\Delta s_t)^2/N_{R_i}}$, respectively.
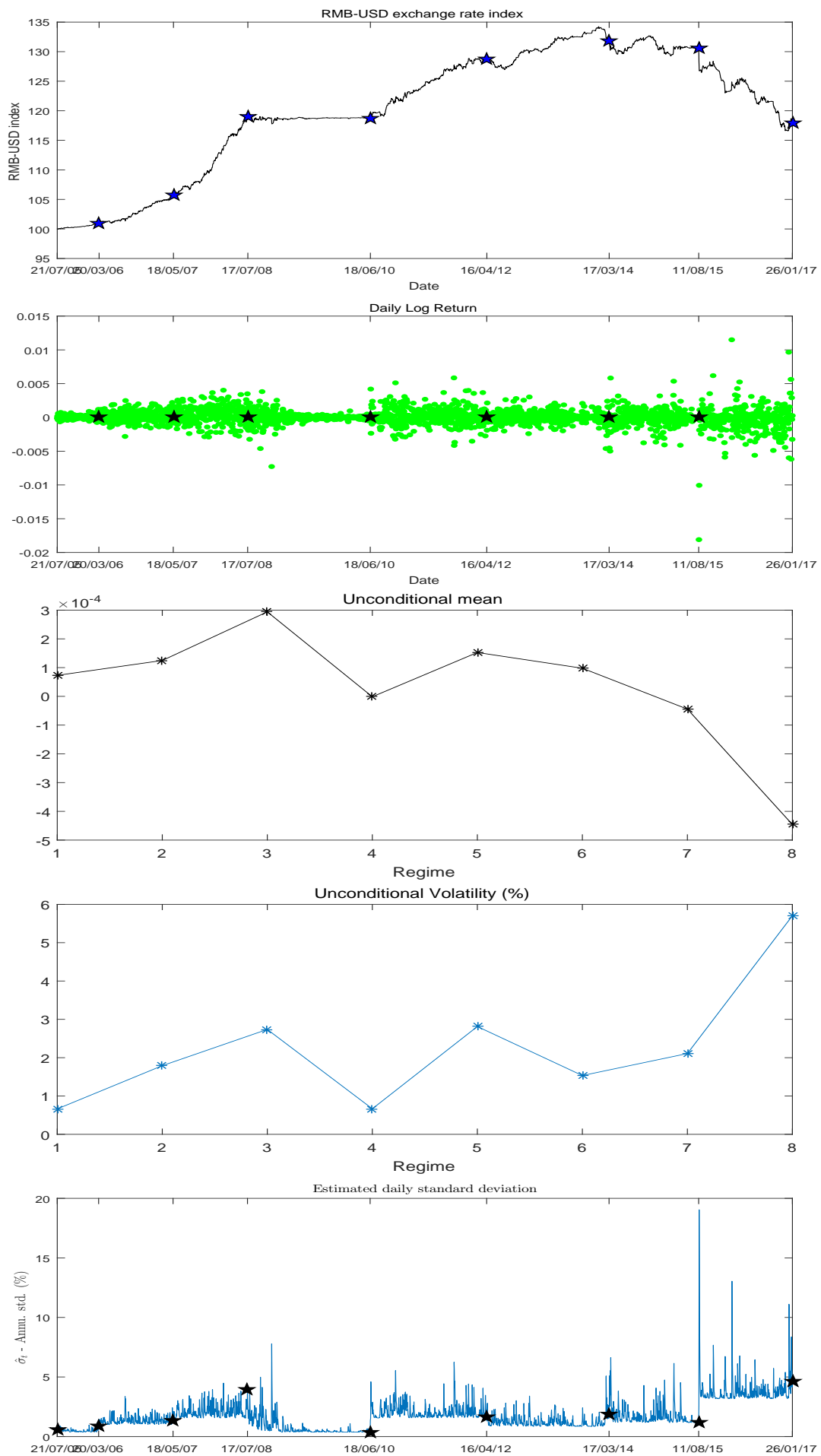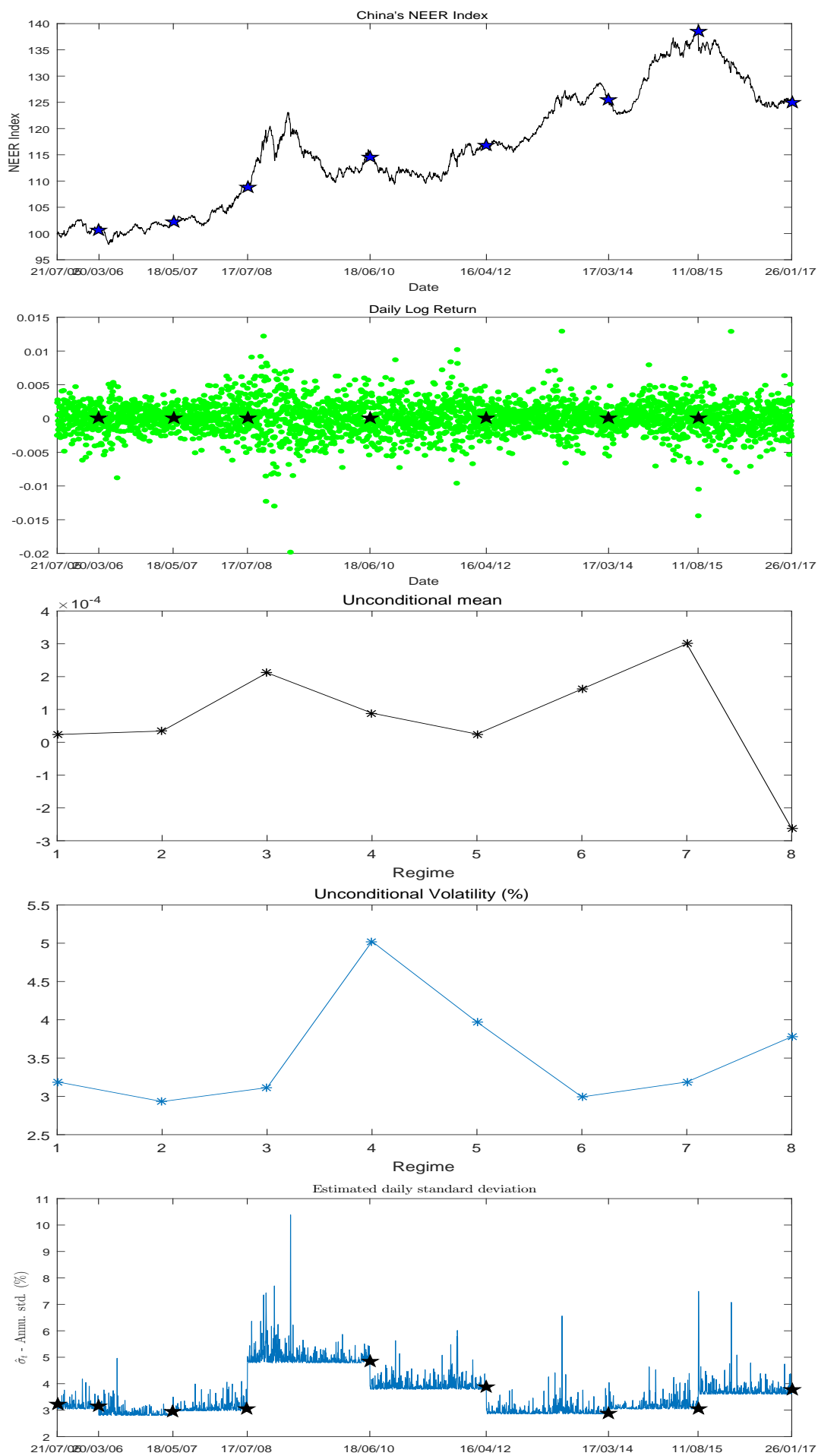
Figure 1: Results for RMB-USD exchange rate.

Figure 2: Results for China's NEER Index.