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► **To cite this version:**

Jinzhao Chen. The "real" exchange rate regime in China since 2015's exchange rate reform. *Asia and the Global Economy*, 2023, 3 (2), pp.100064. hal-04402467

HAL Id: hal-04402467

<https://hal.science/hal-04402467>

Submitted on 18 Jan 2024

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The “*real*” exchange rate regime in China since 2015’s exchange rate reform

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Abstract

Moving away from a fixed exchange rate in 2005, China has gradually enlarged the band of fluctuations of Renminbi (RMB) and implemented various reforms on its central parity to have a more flexible exchange rate regime. This paper studies the nature of the exchange rate regime in China since the exchange regime reform of August 2015. Relying on the self-exciting threshold autoregressive (SETAR) model, it identifies endogenously the band of inaction beyond which the People’s bank of China (China’s central bank) starts to intervene in the foreign exchange market to restrict further fluctuations. Based on the comparison of the estimated threshold with the official band, this paper shows that the RMB/USD exchange rate followed an intermediate regime similar to the crawling band but with only one single threshold of intervention which is much lower than the upper boundary of the announced band.

Key words: Exchange rate regime, self-exciting threshold autoregressive model (SETAR), Renminbi (RMB), Central bank intervention.

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The usual disclaimer applies.

1. Introduction:

With the internationalization of RMB, in October 2016 the International Monetary Fund (IMF) added RMB to the basket of currencies that make up the special drawing rights (SDR). It is lauded as a validation of China's efforts to internationalize its currency, and the SDR membership is perceived to confirm the RMB's global status. Another evidence of its growing importance in the world is the ascension in the currency ranking: RMB had become the fifth most used currency in August 2017 from being the 20th in 2012 (SWIFT, 2017).

The implications of a globalized RMB as an invoice currency and a reserve currency being significant, it is important to understand the determination of RMB exchange rate and its dynamics, and to know if it is market-based or if it is managed through central bank interventions under some motivations. There are three main ones: the first one is to obtain favorable exchange rates to help manufacturing sectors that compete against foreign goods and services and thus boost exports (see Hu et al., 2016 for the case of China and Germaschewski et al., 2022 for the case of Australia), or, on the other extreme, to postpone or limit a devaluation. According to the second motivation, sustained and large interventions have a stabilizing influence in the foreign exchange market in terms of direction and volatility (Kim et al. 2000). In this case, the exchange rate intervention is used as a countercyclical macroeconomic tool aimed at smoothing out short-run currency swings and to limit volatility. Most emerging economies have reformed their exchange rate systems because a stable exchange rate builds confidence in an economy, is favorable for foreign investors and dissuades capital flight of domestic investors. As showed in a series of surveys conducted by the BIS (2005, 2013) and the World Bank (de la Torre et al., 2013), central banks of emerging economies intervene actively, especially in the spot market, to prevent excessive swings of the exchange rate. The third motivation refers to the concerns of long-term misalignments which have impacts on economic growth and financial stability (Kim et al. 2000). It has been proved by a number of successful coordinated international interventions implemented by the major central banks of the world. As the exchange rate is a flexible relative price, to the extent that it is prone to cyclical deviations from its equilibrium, it needs to be contained by active policy (Daude et al., 2016).

Understanding the motivations behind the exchange rate intervention, it is also important to know when the central bank starts to intervene, as it provides some hints about the nature of the exchange rate regime which, in turn, has impact on economic activity. An exchange rate

arrangement that is inconsistent with a country's characteristics can amplify the impact of adverse shocks, impede the control of inflation, undermine economic growth, and increase risks to financial stability (Casiraghi et al., 2022). For developing countries, less flexible exchange rate regimes are associated with slower growth, as well as with greater output volatility (Levy-Yeyati and Sturzenegger, 2003).

To investigate the nature of the exchange rate regime in China since the exchange regime reform in August 2015, this paper applies a self-exiting threshold autoregressive (SETAR) model to identify the band of inaction beyond which the People's Bank of China (PBOC) starts to intervene in the foreign exchange market in opposite directions to contain the RMB/USD exchange rate change within its daily limit of fluctuations. The choice of SETAR model is based on two reasons: first, in the exchange rate regime which operates with interventions, it is quite likely that some form of non-linear structure will be present. SETAR provides a suitable tool to investigate whether this is the case for the exchange rate. Specifically, a two-threshold model might apply, where the thresholds would represent the floor and ceiling of the intervention band in which the exchange rate change is allowed to fluctuate without intervention by the Central Banks. Once outside the band, exchange rate changes revert back to the band following interventions. Second, the SETAR model allows to distinguish intervention from nonintervention regime by identifying unknown thresholds that consist of the band of inaction and indicate the timing of actual intervention.

The empirical results of this study show that the estimated threshold of daily fluctuation of RMB against USD for the period of August 2015 to November 2022 is approximately 0.22%. It is much lower than the upper boundary of the officially announced band widened to 2% prior to the 2015's reform, but much closer to the 0.3% band set in 2005. It means that PBOC is likely to intervene far earlier before the exchange rate appreciation hits the ceiling of 2%. Accordingly, the RMB/USD exchange rate follows an intermediate regime of crawling bands differentiated by a preventive intervention.

The contributions of this study are twofold: first, by employing a different methodology, the SETAR, it contributes to the literature of identification of exchange rate regime for countries in general and for China in particular. The most widely used method (first implemented by Haldane and Hall, 1991) to identify implicit basket pegs consists in relating the rate of return of any given currency i to the return of reference currencies, usually the US dollar, the euro or before 1999 the Deutschmark, and the yen, or even special drawing rights (SDR). Different exchange rate regimes could be identified based on the estimated coefficients of the return of reference currencies included. Bénassy-Quéré et al. (2006) applies an improved version of

this method to 139 currencies while Frankel and Wei (2007), Frankel (2009), and Ma and McCauley (2010) apply it to RMB. Thus, this paper differs from previous ones by first using SETAR model to study RMB exchange rate and de facto exchange rate regime in China. Nevertheless, the SETAR has been used to investigate the exchange rate behavior of other currencies. In the closest work to ours, Chappell et al. (1996) employes a SETAR model to the French Franc/Deutschmark exchange rate, which is restricted to fluctuate between two prescribed bounds as part of the European Exchange rate Mechanism (ERM) in which if the exchange rate moves close to one of the bounds, the French and German central banks are supposed to intervene in the foreign exchange market by buying the weakening currency and with strengthening currency in order to bring the exchange rate back towards the central parity. However, they estimate the threshold models in levels of French franc/Deutschmark exchange rate by assuming the stationarity of this exchange rate while our study focuses on the first difference, i.e., the exchange rate changes, of RMB/USD from which the thresholds are endogenously identified and interpreted as the timing of intervention.

Second, this study provides indirectly a new way to test the effectiveness of actual intervention. In fact, the endogenously estimated threshold implies the moment from which central bank starts to intervene and the exchange rate changes switch to a process of reverting to the band of inaction, the sign of the effectiveness of the intervention. However, in this literature, the natural approach to investigate the effectiveness of intervention consists of examining the impact of central bank intervention on the exchange rates (level or/and volatility) of a currency through regression analysis of different forms: Kim et al., (2000) relies on the Exponential GARCH approach to test the effectiveness of intervention simultaneously on both the mean and the volatility of exchange rate returns of Australian dollar versus US dollar while Germaschewski et al. (2020) uses a structural vector auto regression model (SVAR) to quantify the impact of interventions on the Australian real effective exchange rate. SVAR has also been used to examine the impact of different interventions on the RMB/USD exchange rate changes (Hu and al., 2016). Mirkov et al. (2019) applies the event study to investigate the impact of Swiss National bank intervention on Swiss franc cap against euro.² Daude et al. (2016) estimates the impact of central bank intervention on the variation of the real effective exchange rate for a panel of 18 emerging countries.

² Rosa (2011) applies an event study to investigate the impact of US monetary policy on the level and volatility of US dollar exchange rate returns versus the euro, the Canadian dollar, the British pound and the Swiss franc and the Japanese yen. However, he focuses on the impact of monetary policy instead of policies dedicated to exchange rate.

Eichler and Littke (2018) focuses on the impact of intervention on the volatility of bilateral exchange rate return using a panel fixed effect regression for 62 currencies.

The remainder of this paper is as follows: the second section provides background information, recent developments, and selected literature review; the third section presents the data used in this study and describes the methodology; the fourth section presents the empirical results and final section concludes with policy implications.

2. Background³ and selected literature review

Before the reform of July 2005, China's exchange rate regime was considered as a de facto peg to the US dollar during more than a decade. On July 21st, 2005, the PBOC announced a revaluation of 2.1% of RMB to US Dollar and a reform of the exchange rate regime. It also announced a managed floating exchange rate regime by incorporating a "reference basket" of currencies when choosing its target rate for the RMB. A daily RMB central parity against US Dollar, the fixing, has been established with an initial band of fluctuation set at +/-0.3% around the fixing. Under this new regime, especially from mid-2006 to mid-2008, the RMB started to be managed with reference to a basket of currencies of the main trading partners, instead of being simply pegged to the USD (Ma and McCauley, 2010). As of the end of 2013, the RMB has appreciated almost continually against US dollar from 8.11 RMB per USD to 6 (see Figure 1, upper panel) except during the period of global financial crisis of 2008-2009 in which the PBOC focused on a stable RMB/USD exchange rate. In terms of flexibility, the fluctuation band for RMB exchange rate around the central RMB/USD parity has been gradually widened to +/-0.5% in May 2007, to +/-1% in April 2012 and to +/-2% in July 2014. Since it has moved away from a fixed exchange rate regime and started to reference to a currency basket since 2005, China's exchange rate regime has gone through gradual reforms. However, this does not change the market's focus on the bilateral RMB/USD exchange rate especially in the context of rising US trade deficits and US-China deficits in particular which have often been used as argument to assert the undervaluation of the RMB.

[Insert Figure 1 here]

On August 11th, 2015, the PBOC changed the RMB/USD central parity quoting mechanism, with the intention to enhance the market determination of RMB exchange rate. The daily RMB central parity rate against the US dollar is set with references to the previous day's closing rate, market demand and supply, and valuations of other currencies (People's Bank of

³ This section provides a selective account of major reforms of China's exchange rate regime since 2005. For a detailed description and analysis, see, e.g. Das, (2019).

China, 2015). This revamp of the central parity formation mechanism represents the latest attempt to shift the market's focus on the value of the RMB against the US dollar to one against a currency basket (Cheung et al., 2018). To enhance transparency of its central parity mechanism, in December 2015, CFETS published the "CFETS exchange rate index", a weighted average of multiple bilateral exchange rates dating back to December 31st, 2014, including both its component currencies and their weights in the basket. Later in early 2016, this exchange rate regime was viewed by PBOC as administrative floating with controls and interventions in place to counter volatility caused by speculation (People's Bank of China, 2016).

On May 26th, 2017, CFETS announced that the Chinese banks were required to include a "counter-cyclical adjustment factor" in their quotes of RMB central parity, with the objective of reducing "irrational" depreciation expectations and "pro-cyclical" herding behavior. Nevertheless, the adjustment factor was not defined, with each market-making bank calculating it using its own estimations to reflect its assessment of economic fundamentals. This "counter-cyclical" factor was then phased out in the beginning of 2018 but later reactivated in August 2018 when PBOC also reinstated the reserve requirement of 20% for bank's currency forward transactions amid broad U.S. dollar strength and rising trade tension with US. Those factors, with initial signs of slowdown in the economy, put depreciation pressure on the RMB and other emerging market currencies.

Even though the literature provides mixed evidence on the undervaluation of RMB, in a meta-analysis of RMB misalignment estimates from 95 studies, Cheung and He (2022) finds that the results from the Bayesian model averaging (BMA) meta-analysis and the corresponding median probability model and synthetic practice evaluation do not offer a conclusive statistical inference on RMB misalignment.

As for the nature of the Chinese exchange rate regime, there is no consensus either. On the one hand, there is a perception that the RMB is heavily managed against the US dollar: Frankel and Wei (2007) applies the technique introduced by Frankel and Wei (1994) to estimate implicit basket weights of RMB. Their findings show a de facto regime of peg to the US dollar and a modest but steady increase in flexibility illustrated by a very small weight on regional currencies. Frankel (2009) finds that RMB basket had switched a substantial part of the dollar's weight onto the euro by mid-2007. However, the appreciation of the RMB against the dollar during this period was due to the appreciation of the euro against the dollar. His findings don't make believe that the RMB was being managed against a basket of currencies. Clark (2017) finds that the central parity rate does not consistently guide changes in the RMB/USD rate

during the trading day. Instead, FX intervention to dampen volatility during the trading day has a greater impact on exchange rate movements than the central parity mechanism. On the other hand, in the manner of Haldane and Hall (1991) and Frankel and Wei (2007), complemented with error correction model and graphical analysis, Ma and McCauley (2010) shows that, from mid-2006 to mid-2008, the RMB has been managed against a basket of currencies: RMB's exchange rate crawled against its trading partners' currencies at 2% per annum and within narrow bands of 2%.

From different angles, Cheung et al. (2018) studies RMB central parity mechanism after the August 2015 reform using statistical models. They find that the effect of the RMB currency basket index is revealed important. However, the offshore RMB volatility exerts a dampening effect on its impact on central parity and on the links between the central parity and other determinants. McCauley and Shu (2019) links co-movements between the RMB and other Emerging market currencies with three identified post-2015 reform periods of RMB management: transition, basket management and countercyclical management. They find that the co-movement is the highest in the period of most predictable and multilateral management of the RMB.

Based on a different methodology, the SETAR model, this study implements a univariate analysis of the bilateral exchange rate of RMB against US dollar.

3. Methodology and Data:

As a special version of TAR model (first proposed by Tong, 1978), the self-exciting threshold autoregressive (SETAR) model where the threshold variable is lagged dependent variable, is applied to capture the movements in exchange rates of RMB/USD which are subject to interventions by PBOC. It is employed to allow for distinct types of behavior according to whether the exchange rate movement is close to the predetermined band of fluctuations representing intervention levels.

3.1 SETAR model:

If the RMB is closely linked to the US Dollar as the opinion of some market participants, it is logical to assume the existence of thresholds representing the points at which PBOC intervention occurred to maintain the exchange rate daily variation within its announced band of fluctuation. We might expect there to be two-threshold (three regimes) SETAR model of which the thresholds would represent two boundaries of the band in which the exchange rate is required to stay and fluctuate without intervention by the PBOC. This model can take a

general and unrestricted form as follows:

$$y_t = \begin{cases} \alpha_0^1 + \sum_{i=1}^{P_1} \alpha_i^1 y_{t-i} + \epsilon_t, y_{t-d} \leq r_1 \\ \alpha_0^2 + \sum_{i=1}^{P_2} \alpha_i^2 y_{t-i} + \epsilon_t, r_1 < y_{t-d} \leq r_2 \\ \alpha_0^3 + \sum_{i=1}^{P_3} \alpha_i^3 y_{t-i} + \epsilon_t, y_{t-d} > r_2 \end{cases} \quad (1)$$

y_t is the exchange rate, y_{t-d} is the threshold variable which is the observed lagged exchange rate determining the regime switching points (from regime without intervention to regime with intervention), the delay parameter d is a positive integer, r_1 and r_2 are the thresholds which divide the domain of the threshold variable into 3 regimes. In each different regime, the time series follows a different AR(p) model, $\alpha_i^1, \alpha_i^2, \alpha_i^3$ ($i=0, 1, 2, \dots, p$) are the AR coefficients from regime 1, 2, 3 and may vary from one regime to another, ϵ_t is a zero-mean independently and identically distributed error process. The thresholds r_1 and r_2 and other model parameters can be estimated together with a procedure proposed by Hansen (1999).⁴

Even though the above three-regime SETAR seems well founded theoretically. In practice, however, it is likely that only one threshold will be detected in a particular time series since it is unlikely that the observed series will take values over the full range from lower band to the upper band.⁵ In the case of the RMB/USD, it means that if the RMB was under appreciating pressure against US Dollar during most of the time in the sample period, exchange rate data tend to be often located in the non-intervention regime or upper regime in which PBOC intervenes against further RMB appreciation. So, a SETAR model with only one threshold might also be estimated and compared as expressed in eq. (2), especially if PBOC's intervention was often to contain the pressure of the RMB appreciation against US Dollar rather than the opposite due to the long run appreciating trend of RMB and its limited frequency and extent of depreciation. The estimated single threshold r_1 indicates the timing of this intervention.

$$y_t = \begin{cases} \alpha_0^1 + \sum_{i=1}^{P_1} \alpha_i^1 y_{t-i} + \epsilon_t, y_{t-d} \leq r_1 \\ \alpha_0^2 + \sum_{i=1}^{P_2} \alpha_i^2 y_{t-i} + \epsilon_t, y_{t-d} > r_1 \end{cases} \quad (2)$$

⁴ First, the thresholds and delay parameter d are estimated sequentially by searching over the possible values of threshold variable. Then, with estimated thresholds and threshold variable, the nonlinear least squares methods are used to estimate other parameters of the whole model of three different regimes. Alternatively, it is common to set the delay parameter d to one on theoretical grounds that it is most likely that central bank uses previous day's close price or appreciation rate to determine the bounds of actions, rather than that of two days, or three days ago.

⁵ This is the case for French Franc/Deutschmark exchange rate (see, e.g., Chappell et al. 1996).

3.2 Data:

The exchange rate data employed for SETAR modeling consist of daily closing of RMB/USD exchange rates (US price of one unit of RMB) from August 11th, 2015 to November 30th, 2022, with the start date of the sample corresponding to the date of the exchange regime reform of that year. A positive (negative) percentage change of exchange rate is interpreted as RMB appreciation (depreciation). The natural logarithms of the exchange rate series and their first differences were plotted against time in order (See Figure 2). This study also uses monthly foreign currency reserves data of China for the same sample period. All data are extracted from DataStream.

[Insert Figure 2 here]

Following the conventional practice in the literature, a stationarity check will be made before specifying the nonlinear characteristic of the series. As standard Unit Root (UR) tests are known for being biased toward the non-rejection of a unit root when applied to time series with nonlinear dynamics, here, I apply the NP test of Ng and Perron (2001) and KPSS test which provide an increasing power of the UR test. The results reported in Table 1 show that the exchange rate series (in natural logarithms) has a unit root while its first difference is stationary. In the next section, the first-differenced exchange rate series, i.e., daily exchange rate percentage change are used for estimating a SETAR model. As for linearity check of RMB exchange rate changes, Tsay' test (Tsay, 1989) and Hansen' sup-LR test (Hansen, 1997) are applied. The results reported in Table 2 show the non-linear behavior of daily exchange rate variation.

[Insert Table 1 here]

[Insert Table 2 here]

4. Empirical Results:

Following models are fitted: (1) a SETAR(2) model with a single threshold and two regimes (2) a SETAR(3) model with two thresholds and three regimes.

4.1 SETAR (2) with a single threshold

The results of the estimated SETAR(2) model with one threshold and two regimes are presented in Table 3. The estimated threshold is 0.217%. And the non-linearity tests based on both asymptotic and bootstrapped distributions (with 3000 replications) reject the null hypothesis of one-regime linear AR model whether the alternative hypothesis is the two-regime single-threshold SETAR model (see Table 4) or the three-regime two-thresholds SETAR model (see Table 5). If one accepts the assertion made earlier that the thresholds represent the intervention levels, then this would seem to indicate that PBOC has intervened to pull the positive exchange rate change back towards the band to counter appreciation and volatility whenever the exchange rate variation to previous day is higher than 0.217%. Indeed, the behaviors of the exchange rate changes in both regimes (both coefficients and their respective significance) are quite different. Specifically, when lagged exchange rate appreciation $y(t-2)$ is greater than the identified threshold, 0.217%, the adjustment is obviously quicker in this upper regime than in lower regime where the exchange rate appreciation is lower than the threshold and the behaviors closely approximates a random walk.⁶ In other words, the random walk model operates when daily exchange rate change is lower than the estimated threshold of 0.217%, i.e. at times when the RMB is under no appreciation pressure. The autoregressive model operates with quick adjustments when the exchange rate appreciation is higher than 0.217%, times at which the RMB is under appreciating pressure and intervention by the PBOC might be expected.

[Insert Table 3 here]

[Insert Table 4 here]

[Insert Table 5 here]

4.2. SETAR (3) with two thresholds

The estimated values of SETAR (3) model with two thresholds are given in Table 6. The two estimated thresholds (0.091% and 0.213%) are both positive and too close together to be interpreted as the boundaries of the intervention bands. None of them is negative as one may hypothesize when the RMB depreciation attains a certain level of intervention. One explanation is that, over the period studied, even the RMB had been under downward

⁶ The estimated single threshold is very close (0.21%) when I use a reduced sample (cut at the end of November 2019) by excluding the possible impact of Covid 19. It shows the robustness of estimated threshold to the sample period of Covid 19.

pressures, those pressures were short-lived and during most of the time, the PBOC concerned more about the RMB appreciation and consequently the exchange rate was unlikely to have taken values close to its lower boundary. Anyway, the bootstrapped non-linearity test failed to reject the null of single-threshold model in favor of the two-threshold model (see Table 5). Furthermore, the pattern is very similar for the upper regime when compared with the single-threshold model: both represent a quick adjustment to the band of central bank intervention.

[Insert Table 5 here]

[Insert Table 6 here]

Thus, this two-threshold model appears over parameterized and less relevant with the RMB/USD exchange rate data. Thus, we retain and focus only on the results of the single-threshold model. The results of this model indicate an estimated threshold of daily fluctuation of RMB against USD approximately 0.22%. It is much lower than the upper boundary of the officially announced band widening to 2% prior to the 2015's reform, however, much closer to the 0.3% band set in 2005. It implies that PBOC is likely to intervene far earlier before the exchange rate appreciation hits the ceiling of 2%.

The RMB/USD exchange rate seems to follow an intermediate regime of crawling bands, under which the exchange rate is allowed to fluctuate within a band, around a central parity that is adjusted periodically according to a preannounced schedule (Levy-Yeyati, 2013). One of main critiques on this kind of intermediate regime lies in the fact that it is the existence of a band that makes intermediate regimes potentially crisis-prone. Because it is the obligation to intervene at the edge of a conventional band, to prevent the exchange rate moving outside the band, which can trigger a crisis (Williamson, 2000). However, what is different here is that PBOC started to intervene within the band, far away from the ceiling of the band. It could be interpreted as a preventive measure to remedy the crisis-prone flaw of the crawling bands. All in all, based on the estimated threshold, this regime is much closer to the regime of crawling bands than to a de jure managed floating regime against US dollar.

4.3 Further evidence with foreign reserve data

The estimated threshold of 0.217% implies that when the daily exchange rate appreciation of RMB against US dollar exceeds this threshold, PBOC will intervene in the FX market to contain further RMB appreciation. To corroborate this finding, we try to look at the actual

interventions of PBOC in the FX market and examine if these interventions correspond to reactions to “big” daily changes of RMB exchange rate.

Unfortunately, intervention data are scarce and often substituted for by foreign reserve changes, which may take place for various reasons unrelated to central bank intervention, such as the accrual of interest, the liquidation of foreign currency receipts by public companies, or the rebalances of the reserve buffers driven by prudential considerations (Daude et al., 2016).

Bearing in mind this limit of the data, we investigate if the reserves changes are correlated with the interventions reacted to RMB exchange rate changes exceeding the estimated upper boundary of the band of intervention. First, as the available data of foreign reserves changes are at monthly frequency, we count the number of counter-appreciation interventions per month as the total number of days in which the daily exchange rate change exceeds the estimated threshold of 0.217%. Table 7 shows the result for the sample period. The number 0 means there is no daily exchange rate changes greater than 0.217% and no counter-appreciation intervention either in that month. However, it doesn't mean there are no counter-depreciation interventions. Second, as we failed to identify a significant lower threshold beyond which PBOC intervenes against RMB depreciation, we filter out the months where there are negative foreign reserves changes that may imply counter-depreciation interventions, i.e., diminishing reserves though selling US dollar and buying RMB. Finally, we show in Figure 3 the evolutions of reserves increases and of number of days in which PBOC intervenes against RMB appreciation. The correspondence of these two variables is quite clear even not perfect, because the reserve increases may also be the consequence of other aforementioned factors. The correlation coefficient of these two variables is 0.45 with strong statistical significance.⁷ Though with drawbacks, the data of reserve changes provide some evidence and support for our basic findings.

[Insert Table 7 here]

[Insert Figure 3 here]

5. Conclusion and policy implications:

⁷ It is always significant but a bit lower (0.37) if the whole sample of both positive and negative reserves changes is used.

This paper has applied the SETAR model for studying the RMB/USD exchange rate after the 2015 exchange rate reform, which represents the latest major attempt to shift the market's focus on the value of the RMB against the US dollar to one against a currency basket.

The estimated one-threshold model comprising two regimes shows that the threshold of daily exchange rate variation for the period of August 2015 to November 2022 is approximately 0.22%, while the announced official band has been widened from 0.3% to 2% on the eve of 2015's reform. The estimated threshold is much lower than the upper boundary of this band, which is in accordance with the expectation that PBOC is likely to intervene far earlier before the exchange rate appreciation hits the ceiling of 2%.

The RMB/USD exchange rate seems to follow an intermediate regime of crawling bands. However, in a different manner, PBOC started to intervene when exchange rate change is still within the band, far away from the ceiling of the band. Based on the estimated threshold, this regime is much closer to the regime of crawling bands than to a de jure managed floating regime against US dollar.

Exchange rate intervention has implications for China in terms of domestic monetary policy and development. According to some work (McKinnon and Schnabl, 2009), the increased magnitude of the PBOC's purchases of foreign exchange has led to reserve accumulation and caused the PBOC to lose monetary control, and turned China into an inflationary one in the late 2000s. Further, due to the global financial crisis and the consequent fiscal expansion of four-trillion RMB launched in November 2008, the injection of central government funds to the economy further brought on the inflation. According to others, the trend appreciation of RMB against its trade-weighted basket managed by PBOC with interventions from mid-2006 to mid-2008 serves both to tighten monetary conditions and to maintain some degree of stability and competitiveness in a multicurrency world (Fung et al., 2009). Because with capital controls, the Chinese system features a hybrid of domestic interest rate setting and exchange rate management as joint means to respond to inflation and growth (Ma and McCauley, 2010). Thus, the effectiveness of capital controls, out of scope of this paper, could predetermine those policy implications.

As for implications for other Asian economies, besides the well-established real economy channel through which changes in China's exchange rate alter the relative competitiveness and affect the exports and the overall growth of Asian economies, Shu et al. (2015) finds that changes in the RMB/USD rates in both onshore and offshore markets have a statistically and economically significant impact on changes in Asian currency exchange rates against the US dollar. Two interpretations have been provided: first, the RMB is one component of the

currency basket that Asian central banks implicitly track; second, international investors may consider Asian currencies (including RMB) as having similar risk profiles when deciding to buy and to sell. As RMB/USD exchange rate continues to trade in a narrow range on a daily basis, other Asian currencies have to be contained in a narrow band with USD with intervention if they implicitly track RMB. A key question is whether the tension between tight short-term control and desired longer-run flexibility in China is sustainable or increase the risk of disruptive adjustment in China and other partner economies in Asia through spillover because of the linkage between RMB/USD exchange rate changes and changes in Asian currency rates against the US dollar. A broader issue will be the impact of exchange rate intervention on economic activity in a cross-country setting, as investigated empirically by some studies (see, e.g., Daude et al., 2016 for a study of 18 emerging economies, Germaschewski et al., 2022 for the impact of the Reserve Bank of Australia's oral intervention on the Australian dollar and output growth). Those important issues are beyond the scope of this paper and are worth of future research.

Acknowledgements

The author thanks Mathieu Mercadier, Ali Kutan, two anonymous reviewers, and participants at the SSEM panel at the 2022 Asia Economic Community Forum for their valuable discussions and comments.

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Tables and Figures

Table 1: Unit-root tests

Period	N-P ADF model			KPSS	
	MZa	MZt	Trend/Constant	LM-Stat.	Trend/Constant
Level	-2.47059	-0.98696	Trend	16.66370 ***	Trend
Level	0.83630	0.45305	Constant	18.53825 **	Constant
1st difference	-14.8854 ***	-2.47960 **	Constant	0.210475	Constant

Notes: the number of lags is auto selected by minimizing the SIC criteria. *, **, and *** denote significance at the 10, 5, and 1 percent levels, respectively.

Table 2: Non-linearity tests

Null Hypothesis: No threshold nonlinearity	Tsay test		Hansen sup-LR test	
	d=1	d=2	d=1	d=2
Trimming percentage (%)	10	10	10	10
F-stat. for null hypothesis of no threshold	1.3716	2.3853	35.2170	37.6193
P-value	0.2042	0.0148**	0***b	0***b

Notes: autoregressive order p is set at 7 to reduce the errors to white noise; d is the delay order; b denotes bootstrap P-Value; *, **, and *** denote significance at the 10, 5, and 1 percent levels, respectively.

Table 3: Estimated coefficients for SETAR Model with 1 threshold

$$y_t = \begin{cases} \alpha_0^{lower} + \sum_{i=1}^7 \alpha_i^{lower} y_{t-i} + \epsilon_t, & \text{if } y_{t-2} \leq 0.217 \\ \alpha_0^{upper} + \sum_{i=1}^7 \alpha_i^{upper} y_{t-i} + \epsilon_t, & \text{if } y_{t-2} > 0.217 \end{cases}$$

Variable	Below threshold $y_{t-2} \leq 0.217$		Above threshold: $y_{t-2} > 0.217$	
	Estimate	St Error	Estimate	St Error
Constant	-0.000503	0.005792	-0.000964	0.044578
y(t-1)	0.03476	0.037069	-0.150581	0.068507**
y(t-2)	0.041545	0.047596	-0.079915	0.098355
y(t-3)	0.081609	0.030993***	-0.125802	0.066585*
y(t-4)	0.016731	0.031094	0.124226	0.084805
y(t-5)	0.066372	0.028571**	0.059616	0.078638
y(t-6)	0.000981	0.03174	-0.030087	0.100454
y(t-7)	-0.023369	0.03107	0.173723	0.069137**
Observations	1672		199	
Percentage	89		11	
Regime Variance	0.058		0.066	

Notes: to make each regime have a non-trivial proportion of observations in the limit and to make the asymptotic inference on SETAR models to work correctly, 10% of the series are trimmed and not used when searching for the values of thresholds (Hansen, 1999); *, **, and *** denote significance at the 10, 5, and 1 percent levels, respectively.

Table 4: Tests of linear SETAR(1) against two-regime SETAR(2)

Delay	F-stat	Asymptotic p-values	Bootstrapped p-values
2	37.37459	0.001	0.011

Note: 3000 bootstrap replications.

Table 5: Bootstrap tests against SETAR(3)

	F-stat	Bootstrap p-values
Bootstrap tests of SETAR(1) against SETAR(3)	49.277292	0.816
Bootstrap tests of SETAR(2) against SETAR(3)	11.669593	0.817

Note: 3000 bootstrap replications.

Table 6: Estimated coefficients for SETAR Model with 2 thresholds

$$y_t = \begin{cases} \alpha_0^{lower} + \sum_{i=1}^7 \alpha_i^{lower} y_{t-i} + \epsilon_t, & \text{if } y_{t-2} \leq 0.091 \\ \alpha_0^{middle} + \sum_{i=1}^7 \alpha_i^{middle} y_{t-i} + \epsilon_t, & \text{if } 0.091_1 < y_{t-2} \leq 0.213 \\ \alpha_0^{upper} + \sum_{i=1}^7 \alpha_i^{upper} y_{t-i} + \epsilon_t, & \text{if } y_{t-2} > 0.213 \end{cases}$$

Variable	Below lower threshold $y_{t-2} \leq 0.091$		between thresholds: $0.091 < y_{t-2} \leq 0.213$		Above upper threshold $y_{t-2} > 0.213$	
	Estimate	St Error	Estimate	St Error	Estimate	St Error
Constant	0.002495	0.007414	-0.075906	0.05789	0.004054	0.042339
y(t-1)	0.048152	0.041169	-0.062103	0.081918	-0.141559	0.065508**
y(t-2)	0.050807	0.057629	0.508743	0.396813	-0.086786	0.095192
y(t-3)	0.100527	0.034711***	-0.028221	0.061906	-0.124459	0.064823*
y(t-4)	0.012435	0.034532	0.038608	0.067213	0.125333	0.079901
y(t-5)	0.074287	0.031569**	-0.016899	0.061379	0.056409	0.078039
y(t-6)	-0.005977	0.035257	0.069144	0.0609	-0.029431	0.099984
y(t-7)	-0.006445	0.032615	-0.165543	0.094228*	0.176762	0.069323**
Observations	1399		267		205	
Percentage	75		14		11	
Regime Variance	0.060		0.046		0.065	

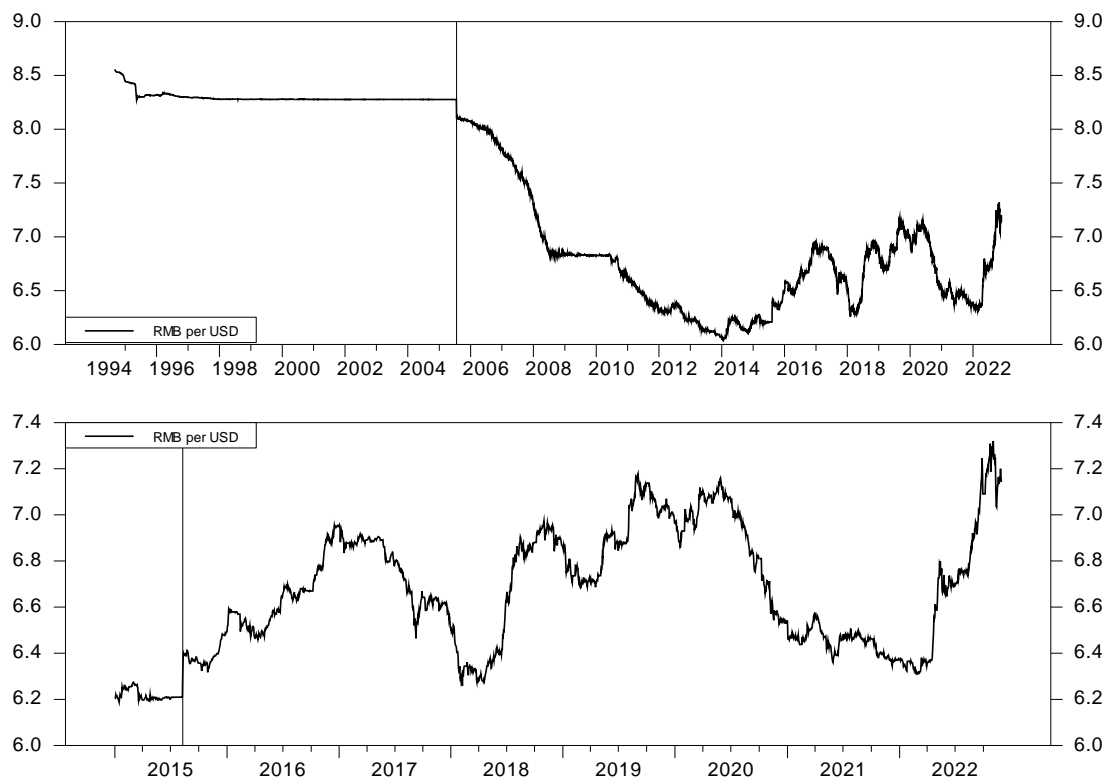
Notes: to make each regime have a non-trivial proportion of observations in the limit and to make the asymptotic inference on SETAR models to work correctly, 10% of the series are trimmed and not used when searching for the values of thresholds (Hansen, 1999); *, **, and *** denote significance at the 10, 5, and 1 percent levels, respectively.

Table 7: Estimated monthly exchange rate interventions against RMB appreciation.

Year\Month	1	2	3	4	5	6	7	8	9	10	11	12
2015								1	0	2	0	0
2016	0	1	5	0	0	1	0	4	1	0	0	0
2017	5	0	0	0	2	4	2	5	6	2	2	5
2018	7	6	2	1	4	0	3	5	1	0	3	4
2019	7	3	1	1	0	3	1	1	6	4	1	3
2020	3	4	4	2	0	3	5	5	3	3	7	1
2021	3	1	1	4	6	1	2	0	1	1	0	1
2022	1	1	2	1	4	5	1	4	3	1	9	
Total	26	16	15	9	16	17	14	25	21	13	22	14

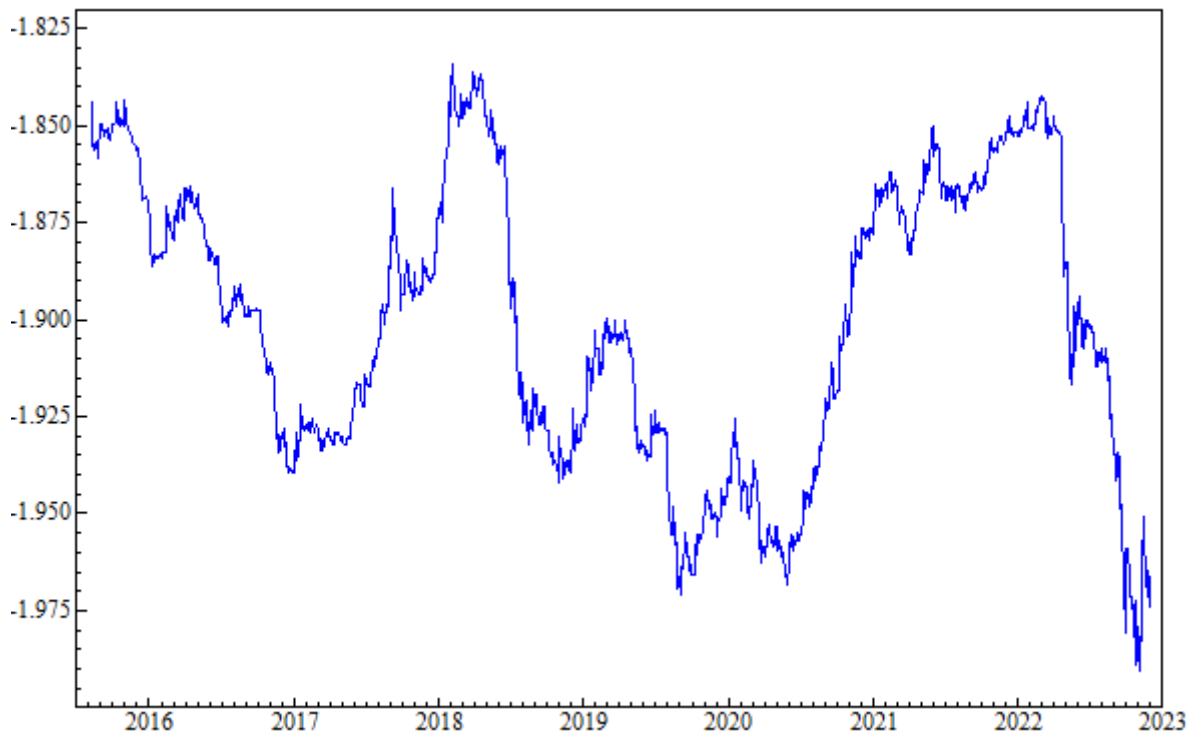
Note: the number of each month represents the total number of days in which the daily percentage appreciation is higher than the estimated threshold of 0.217%.

Figure 1: RMB/USD exchange rate from 1994 to 2022 (RMB per USD, daily)

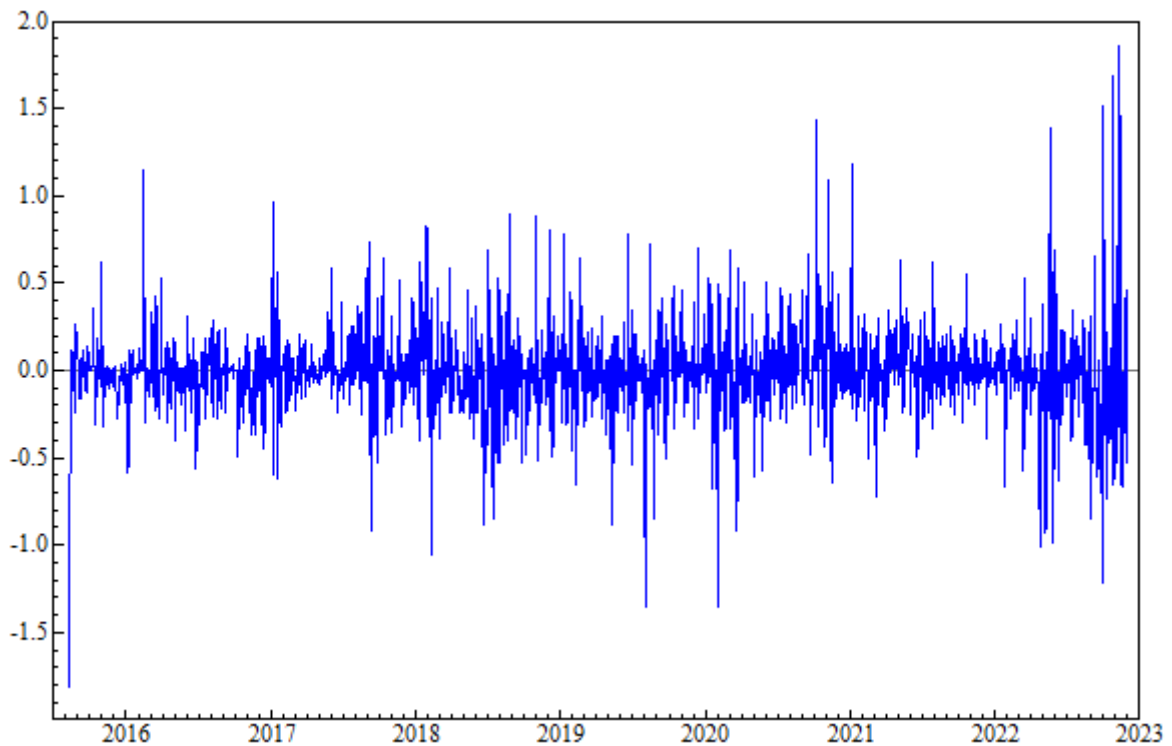


Source: Datastream

Figure 2: RMB/USD exchange rate in natural log and in first difference from August 11th, 2015 to November 30th, 2022 (USD per RMB, daily)



(a) Natural logarithm of RMB/USD exchange rate



(b) First differences of natural logarithm of RMB/USD exchange rate

Figure 3: Reserve changes and Monthly number of interventions

