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Diversifying reference currency basket and decreasing degree of flexibility in exchange policy of China

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ABSTRACT

This study aims to determine the *de facto* foreign exchange rate regime of the renminbi (RMB) from 2005 to 2016. To address this problem, I employ the implicit currency basket model proposed by Frankel and Wei (1994) to estimate the components of RMB's reference currency basket and the exchange rate flexibility model with a Markov-switching process to identify the possible regime switches. The main findings are as follows. First, the implicit currency basket model shows that the US dollar is still the anchor currency of RMB, with the highest weight in RMB's reference basket, although it has decreased since August 2015. Second, the regime switches evaluated by examining exchange rate flexibility show that the regime differed over time. Indeed, the Chinese monetary authorities implemented heavy regulations on RMB flexibility under unstable external conditions such as the global financial crisis and period of RMB depreciation.

Key words: foreign exchange rate regime, currency basket, renminbi, exchange rate flexibility

JEL Classification: E58, F31

1. Introduction

Clarifying the implemented renminbi (RMB hereafter) exchange rate regime is crucial because of the widespread "*de facto* vs. *de jure*" problem (Calvo & Reinhart, 2002; Frankel & Wei, 1994; Levy-Yeyati & Sturzenegger, 2005; Obstfeld & Rogoff, 1995), which is characterized by monetary authorities implementing different foreign exchange policies from what they officially claim to follow, particularly in emerging countries. In July 2005, China announced that it was shifting the RMB exchange rate regime from a dollar-peg to managed floating with reference to a currency basket, without publishing the details of the basket components. Since 2009, when China promoted its RMB internationalization program, RMB has been considered to be a potential way of diversifying global reserve currencies in the international monetary system (Ito, 2017; Kawai & Pontines, 2016), especially after RMB was included in the IMF's special drawing right (SDR) basket in 2016. The increased importance of RMB again raised the question of what is the *de facto* exchange rate regime of RMB, especially considering recent RMB depreciation and the RMB reforms in August 2015 designed to make the currency more market-based (see Appendix 1 for the details of these reforms).

Previous studies have often discussed the *de facto* RMB exchange rate regime. For example, the Frankel–Wei model (1994, 2008) is widely used to estimate the components of the implicit currency basket. The early debate on the RMB exchange rate regime focused on whether the US dollar-peg was to be retained for the implementation of the managed floating regime with a reference currency basket. Many scholars have argued that the US dollar was still the single anchor of RMB before the global financial crisis (GFC) in 2008–2009, meaning that the so-called managed floating regime is similar to a crawling-peg regime with a US dollar anchor (Eichengreen, 2007; Frankel & Wei, 2008; Ito & Orii, 2006; Moosa, Naughton, & Li, 2009; Ogawa & Sakane, 2006; Zeileis, Shah, & Patnaik, 2010). In addition, the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER) classifies RMB as a crawling-like arrangement, in that "*a currency appreciates or depreciates in a sufficiently monotonic and continuous manner with a narrow margin of 2% for at least six months*," rather than as a "floating" currency. Because the official China Foreign Exchange Trade System (CFETS) RMB index published in 2015 provides new evidence of the components of RMB's reference basket, it is employed in this study to analyze the implicit basket of RMB and possible regime-switching points.

Moreover, many researchers have also argued that the degree of exchange rate flexibility is a good measure for capturing the evolution of a country's exchange rate regime because of the "fear of floating"; in other words, monetary authorities do not always let their currencies flexibly float as they claim (Calvo & Reinhart, 2002; Dixon, Zhang, & Dai, 2016; Levy-Yeyati & Sturzenegger, 2005). Furthermore, Dixon et al. (2016) proposed defining an exchange rate regime in terms of the degree of exchange rate flexibility under a Markov-switching (MS) process, thereby providing a method other than the Frankel–Wei model to identify the regime-switching points of RMB. This method is also used herein to reveal the *de facto* exchange rate regime of RMB.

The findings of the present study show that the "*de facto* vs. *de jure*" problem existed from 2005 to 2016. During this period, the *de jure* RMB exchange rate regime was managed floating with reference to a currency basket. On the contrary, the *de facto* regime was a dollar-peg during the GFC in 2008–2010. In addition, during 2005–2008 and 2010–2015, the US dollar's weight in the implicit RMB currency basket was near to unity, meaning that the RMB exchange rate regime was a crawling-peg with the US dollar as the only anchor rather than a currency basket. Furthermore, after the RMB reforms in August 2015, the US dollar's weight decreased to about 0.86, showing that the RMB exchange rate regime is more likely to be a currency basket because of its more diversified components compared with before 2015. Finally, the results of the foreign exchange flexibility model show that China has adjusted its regulation on exchange rate flexibility according to different external environments. The empirical results reveal that under unstable situations such as the GFC and European debt crisis, RMB flexibility was heavily regulated, especially after the RMB reforms in August 2015.

The rest of this paper is organized as follows. Section 2 explains the methodologies used in this study. Section 3 reports the results and Section 4 contains the conclusions and implications of the study.

2. Econometrics Methodology

2.1 Implicit currency basket model (the Frankel–Wei model)

The People's Bank of China (PBOC), the Chinese central bank, announced a regime switch from a dollar-peg to a managed floating regime in July 2005. Since then, the RMB exchange rate has been managed by referring to a currency basket; however, the details of the basket have not been published. In this study, the implicit currency basket model proposed by Frankel and Wei (1994, 2008)[1)] is employed to estimate the components and weights of RMB's implicit currency basket, written as

$$RMB_t = \sum_{i=1}^{n} \omega_t \cdot X_{i,t} \tag{1}$$

where RMB_t is the exchange rate of RMB against one numeraire currency at time t; $X_{i,t}$ is the exchange rate of reference currency i against the numeraire; n kinds of currencies are included in the basket; and ω_i represents the weight of currency i. The exchange rate of RMB against one numeraire currency is considered to be a weighted sum of the exchange rates of the components in the basket against the numeraire. Moreover, there are no constant or error terms on the right-hand side of the equation if the currency basket is perfect. To avoid the non-stationarity problem, the logarithm returns of the exchange rate were used. Furthermore, Frankel and Wei (1994, 2008) suggested using logarithm returns rather than nominal returns to avoid the non-stationarity problem, written as

$$\Delta \ln RMB_t = c + \sum_{i=1}^{n} \left[\omega_t \cdot \Delta \ln\left(X_{i,t}\right)\right] + u_t \tag{2}$$

where the constant c represents the gradual crawling trend (either appreciation or depreciation) of RMB against the entire currency basket. u_t is the error term, showing the differential from the rate decided by the basket. The Mexican peso was chosen as the numeraire, as it is not included within the right-hand side and satisfies the "*floating*" and "*remote*" selection criteria suggested by Frankel and Wei (1994)[2)]. In addition, it is a "*tradable*" currency in the domestic interbank market.

Regarding data frequency, although many studies have used monthly exchange rates to estimate implicit currency baskets, this study employed daily exchange rates, because the effects of intervention may be eliminated during the month (Frankel & Xie, 2010; Zeileis et al., 2010). An ordinary least squares regression was employed for the estimation. Additionally, the weights in the Frankel–Wei model are not necessarily positive because they are proxied for by the estimated co-movement between RMB and one component currency. Hence, a negative weight for a certain foreign currency in the basket realistically reflects its negative correlation with RMB in a certain period (Branson & Katseli, 1982; Edison & Vårdal, 1990; Zhang, Shi, & Zhang, 2011).

Furthermore, structural changes in RMB's reference basket may have occurred within the analysis period owing to the inconsistency of the basket components. Given that the details of the PBOC's interventions are also unpublished, the structural change test proposed by Bai and Perron (2003) was employed to verify the multiple structural break points in a linear regression, based on the residual sum of squares (Frankel & Xie, 2010; Zeileis et al., 2010).

2.2 Exchange rate flexibility model

Following Levy-Yeyati and Sturzenegger (2005), the differential of the exchange rate flexibilities between multiple currencies was used to distinguish between exchange rate regimes. Because RMB is different from the domestic exchange market, it could be traded in global financial markets such as Hong Kong and New York without the PBOC's interventions. If the US dollar is the single anchor of RMB, the RMB/USD rate in the domestic market is presumed to be the PBOC's initial interventional target. Hence, Dixon et al. (2016) built a flexibility index Fle_index_t, represented by the differential of RMB/USD rate flexibilities between the domestic and global markets, to evaluate the PBOC's regulatory effect on the domestic market, written as

$$Fle\_index_t = 100 \times \frac{Reletive\ Volatility\ Ratio_t}{Reference\ Base} = 100 \times \frac{sd(D)_{t-20,t} / sd(G)_{t-20,t}}{Reference\ Base} \tag{3}$$

The steps of this process are as follows. First, *Relative Volatility Ratio*$_t$ is built to evaluate the relative degree of volatility in the domestic market ($sd(D)_{t\text{-}20,t}$) against that in the global market ($sd(G)_{t\text{-}20,t}$), represented by the standard deviations of daily RMB/USD logarithm returns within 21 days (one trading month) both domestically and globally. Then, *Reletive Volatility Ratio*$_t$ is divided by *Reference Base*, the ratio on a specific date as the base, to create an index. As cross-border capital flows are restricted in Mainland China, heavy regulations (such as interventions) on the RMB/USD rate in the domestic market lower Fle_index_t during a specific period. Meanwhile, deregulations in the domestic market raise Fle_index_t.

Furthermore, because Fle_index_t proxies for the flexibility of the regulated RMB rate compared with the unregulated RMB rate, it is assumed to have different adjustment processes when monetary authorities heavily or lightly regulate the RMB exchange rate. Hence, Dixon et al. (2016) applied an MS framework to reveal the regime changes in the RMB exchange market evaluated by Fle_index_t, written as

$$\begin{aligned} &Fle\_index_t = \alpha(s_t) + \beta\left[Fle_{index_{t-1}} - \alpha(s_{t-1})\right] + \varepsilon_t \\ &\text{Regime variable:} \\ &s_t = \begin{cases} 1 \text{ high} - \text{flexibility regime} \\ 2 \text{ low} - \text{flexibility regime} \end{cases} \text{when } \alpha(s_t = 1) > \alpha(s_t = 2) \end{aligned} \tag{4}$$

where two flexibility regimes (or two states), namely a high-flexibility regime and low-flexibility regime, are included in the MS framework, which is identified by an unobservable regime variable s_t. $s_t = 1$ shows the high-flexibility regime with light regulations and $s_t = 2$ shows the low-flexibility regime with heavy regulations. The mean (constant) term coefficient $\alpha(s_t)$ depends on s_t, while the autoregressive coefficient β is unconditional on s_t. The error term ε_t follows a usual i.i.d assumption. Because flexibility is larger on average in the high-flexibility regime than in the low-flexibility regime, the mean coefficient $\alpha(s_t)$ should fulfill $\alpha(s_t = 1) > \alpha(s_t = 2)$, which is employed as the criterion to identify the two possible regimes. Under the MS framework, the regime variable s_t at each time point t can be estimated (Hamilton, 1994). Hence, Dixon et al. (2016) suggested that the regime-switching points can be adopted to identify different exchange rate regimes from the perspective of their exchange rate flexibility. Moreover, they proposed an extended MS model by adding some of the possible driving factors of the flexibility index into the standard MS model in Eq. (4) as a robustness check, written as

$$\begin{aligned} & Fle\_index_t = \alpha(s_t) + \beta[Fle\_index_{t-1} - \alpha(s_{t-1})] + \sum \gamma_i \cdot Z_{i,t} + \varepsilon_t \\ & \text{Regime variable:} \\ & s_t = \begin{cases} 1 \text{ high} - \text{flexibility regime} \\ 2 \text{ low} - \text{flexibility regime} \end{cases} \text{when } \alpha(s_t = 1) > \alpha(s_t = 2) \end{aligned} \tag{5}$$

where $Z_{i,t}$ and γ_i represent the additional driving factors and their coefficients, while γ_i was hypothesized to be unconditional on the regime variable s_t. Eq. (5) uses the same criterion to identify the two possible regimes as before.

Dixon et al. (2016) suggested two possible driving factors. The first one, CDS_DIF, represents the spread of credit default swaps between China and the United States. This is employed to proxy for the sovereign risk differential. The differential between domestic and global sovereign risk drives capital to flow to low-risk nations owing to risk aversion, leading to RMB appreciation in the domestic market and thus a higher flexibility index, although capital restrictions do suppress this effect. Hence, the sign is hypothesized to be negative.

The second one is exchange market pressure (EMP), a variable adopted to evaluate the intervention effect by using official foreign reserves. Emerging countries are assumed to directly intervene in foreign exchange markets by using official foreign reserves to lower exchange rate volatility (Frankel & Wei, 1994, 2008; Levy-Yeyati & Sturzenegger, 2005). In this study, the form of daily-based EMP supposed by Frankel and Xie (2010) is employed, which is written as

$$EMP_t = \Delta \ln X_t + \Delta \ln(FR_t / MB_t) \tag{6}$$

where X_t, FR_t, and MB_t represent the RMB/USD rate in the domestic market, official Chinese foreign reserves, and Chinese monetary base (M2), respectively. Additionally, daily-based FR_t and MB_t are converted from the published monthly data by using a cubic spline interpolation. Hence, the sign of EMP is hypothesized to be negative.

Moreover, this study adds another possible driving factor to extend the MS model, namely the interest rate differential between the domestic and global markets (INT_DIF). In reference to interest rate parity theory, higher domestic interest rates lead to a higher RMB rate in the domestic market and thus a higher flexibility index, although capital controls do minimize this effect. Therefore, the sign of INT_DIF's coefficient is hypothesized to be positive.

3. Empirical Results

3.1 Implicit currency basket model (Frankel–Wei model)

The data for the daily foreign exchange rates were collected from DataStream. The study period, which runs from July 21, 2005 to July 29, 2016, is divided into three subperiods: the pre-crisis period from July 21, 2005 to July 15, 2008 when a managed floating regime was implemented; the in-crisis period from July 16, 2008 to June 18, 2010 when the RMB/USD exchange rate was the *de facto* dollar-peg during the GFC; and the post-crisis period from June 21, 2010 to July 29, 2016. The models for each sub-period are then compared.

Thirteen currencies are included in the RMB index: the US dollar (USD), euro (EUR), Japanese yen (JPY), British pound (GBP), Australian dollar (AUD), Canadian dollar (CAD), Swiss franc (CHF), Hong Kong dollar (HKD), Malaysian ringgit (MYR), New Zealand dollar (NZD), Russian ruble (RUB), Singapore dollar (SGD), and Thai baht (THB). As the US dollar is RMB's single anchor and dominates the weight in the basket, filtering on these 13 currencies is essential for restraining multicollinearity. First, the Singapore dollar, Thai baht, and Hong Kong dollar were excluded from the model because of their extremely high correlations with the US dollar (see Table 1). The Malaysia ringgit was also excluded thanks to the high similarity between its reference basket and that of RMB (Rajan, 2012). Meanwhile, the Russian ruble was excluded owing to its violent fluctuations against other currencies since 2014 when the oil price dropped sharply. Therefore, eight currencies were chosen from the CFETS RMB index as the components on the right-hand side of Eq. (2).

Table 2 displays the estimated results of the Frankel–Wei models. The results of the pre-crisis period in Column (1) and in-crisis period in Column (2) show that the weight of the US dollar is nearly unity (0.952 and 0.984, respectively), confirming that it was the single anchor of RMB before 2010. Although the coefficients of some of the currencies (e.g., the euro) are significant in the pre-crisis and in-crisis periods, the weights of all the currencies except the US dollar are lower than 0.05. The constant in the pre-crisis period is −0.022 (daily, or −5% yearly), showing the steady appreciation trend of RMB against the whole basket before the GFC. In the in-crisis period, the RMB exchange rate is shown to be an anchor only for the US dollar, without a significant trend. These results show that before the GFC, Chinese monetary authorities implemented a crawling-peg with a steady appreciation trend, in which the US dollar was the only anchor. Later, in the in-crisis period, fixing RMB to the US dollar led to a higher weight for the US dollar and an extremely high R2 of the Frankel–Wei model. Referring to previous studies using the

Frankel–Wei model to estimate the RMB currency basket, Frankel and Wei (2008) proposed that the US dollar's weight in the RMB currency basket was 1.07 from 2005 to 2008, with the SDR as the numeraire currency.

Further, according to Zeileis et al. (2010), the US dollar's weight was 0.969 from March 2006 to August 2008, with the Swiss franc as the numeraire. In summary, the above results for the pre-crisis and in-crisis periods are similar to those in the literature, confirming that the US dollar had a dominantly high weight in the RMB reference basket despite different numeraire selections.

I now concentrate on the RMB regime since 2010 when it switched from a dollar-peg to managed floating. Column (3) shows the estimated results for the post-crisis period from June 21, 2010 to July 29, 2016, while Columns (4) and (5) show the estimated results in the sub-periods separated by the structural change (Bai & Perron, 2003). The only break point at a 5% significant level is August 8, 2015, which is the same as the adjustment of RMB's official rate, and this divides the post-crisis period into two subperiods: Sub-period 1 and Sub-period 2.

Referring to the estimated coefficients, the US dollar had the highest weight in the basket (0.93, significant at 1% level). The weights of the other currencies were far lower, and not all the results were significant. The constant term shows an average daily appreciation trend of RMB against the whole basket, although this is not significant. Comparing the results for Sub-period 1 (in Column (4)) with those for Sub-period 2 (in Column (5)), the weight of the US dollar significantly decreases from 0.95 to 0.86, while the weights of the other main reserve currencies (euro, yen, and pound) increase and become significant; however, the weights of the Australian dollar, New Zealand dollar, Canadian dollar, and Swiss franc remain almost constant. The constant

Table 1. Correlations among the exchange rates

	AUD	CAD	CHF	CNY	EUR	GBP	HKD	JPY	MYR	NZD	RUB	SGD	THB	USD
AUD	1.00													
CAD	0.78	1.00												
CHF	0.20	0.45	1.00											
CNY	0.08	0.44	0.91	1.00										
EUR	0.28	0.54	0.83	0.72	1.00									
GBP	0.05	0.40	0.91	0.94	0.79	1.00								
HKD	0.10	0.50	0.89	0.97	0.75	0.95	1.00							
JPY	0.79	0.79	0.10	–0.03	0.28	0.02	0.11	1.00						
MYR	0.69	0.81	0.47	0.49	0.48	0.42	0.50	0.55	1.00					
NZD	0.32	0.45	0.83	0.84	0.69	0.78	0.76	0.01	0.60	1.00				
RUB	0.25	–0.06	–0.75	–0.83	–0.50	–0.81	–0.84	0.27	–0.13	–0.58	1.00			
SGD	0.28	0.59	0.94	0.96	0.80	0.93	0.95	0.16	0.61	0.88	–0.75	1.00		
THB	0.29	0.62	0.85	0.90	0.70	0.84	0.94	0.25	0.63	0.73	–0.75	0.93	1.00	
USD	0.10	0.50	0.89	0.97	0.75	0.94	1.00	0.11	0.50	0.75	–0.84	0.95	0.95	1.00

All variables are the daily exchange rates of one currency against the Mexican peso.

terms are −0.007% and 0.023% daily (or −1.87% and 5.83% yearly) in the two subperiods, showing a significant change in the crawling policy of the PBOC since the reforms in 2015.

This study used *t*-tests on the difference between the coefficients in Sub-periods 1 and 2 for a robustness check. The null hypothesis was (5)−(4) = 0, meaning that there was no structural change in either of the sub-periods. The results show that the null hypotheses on the constant term and the US dollar, euro, yen, and pound were rejected, demonstrating that the changes in the crawling trend and weights of the main reserve currencies led to the structural change in RMB's reference basket. In addition, as the weights of the Australian dollar, New Zealand dollar, Canadian dollar, and Swiss franc did not structurally change to a significant degree, the constraint that the weights of these four currencies were stable and unchanged was added into the Frankel–Wei model with a structural change. Columns (7) and (8) display the results, while Column (9) shows the *t*-test results for the null hypothesis that (8)−(7) = 0. There was one structural

Table 2. Results of the Frankel–Wei model

	Pre-crisis 2005–2008	In-crisis 2008–2010	Post-crisis 2010–2016	Sub-period 1	Sub-period 2	Difference (5)–(4)	Sub-period 1'	Sub-period 2'	Difference (8)–(7)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
C	–0.022%***	–0.002%	–0.002%	–0.007%**	0.023%***	0.031%***	–0.007%**	0.024%***	0.031%***
	(0.004%)	(0.004%)	0.003%	(0.004%)	(0.009%)	(0.009%)	(0.004%)	(0.009%)	(0.009%)
USD	0.952***	0.984***	0.93***	0.951***	0.857***	–0.094***	0.952***	0.86***	–0.092***
	(0.013)	(0.008)	(0.009)	(0.01)	(0.02)	(0.022)	(0.01)	(0.019)	(0.021)
EUR	–0.03	0.031***	–0.014	0.004	–0.068**	–0.071**	0.003	–0.037*	–0.04**
	(0.021)	(0.012)	(0.008)	(0.009)	(0.03)	(0.031)	(0.009)	(0.019)	(0.02)
JPY	0.015*	–0.002	0.009	0.006	0.035**	0.029*	0.005	0.04***	0.035**
	(0.009)	(0.006)	(0.006)	(0.007)	(0.014)	(0.016)	(0.007)	(0.014)	(0.015)
GBP	–0.005	0.01*	0.029***	0.011	0.045***	0.034*	0.01	0.044***	0.033**
	(0.01)	(0.006)	(0.008)	(0.01)	(0.014)	(0.017)	(0.01)	(0.014)	(0.017)
AUD	0.003	–0.004	0.017*	0.018*	0.025	0.006	0.02**		–
	(0.01)	(0.006)	(0.009)	(0.01)	(0.02)	(0.022)	(0.009)		–
NZD	0.01	0.003	0.005	0.005	0.007	0.002	0.005		–
	(0.008)	(0.007)	(0.008)	(0.009)	(0.016)	(0.018)	(0.008)		–
CAD	–0.007	–0.007	0.007	0.006	–0.006	–0.012	0.004		–
	(0.008)	(0.006)	(0.01)	(0.011)	(0.021)	(0.024)	(0.01)		–
CHF	0.044**	–0.016	0.002	0.001	0.042	0.041	0.003		–
	(0.018)	(0.01)	(0.006)	(0.006)	(0.03)	(0.03)	(0.006)		–
Obs.	777	503	1595	1338	257	–	1338	257	–
R2	0.941	0.994	0.957	0.959		–	0.959		–

This table displays the estimated weights of the reference currencies by using the daily-based implicit currency basket model in Eq. (2). Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Columns (1), (2), and (3) show the results for the pre-crisis period (July 21, 2005 to July 15, 2008), in-crisis period (July 16, 2008 to June 18, 2010), and post-crisis period (June 21, 2010 to July 29, 2016), respectively. Sub-periods 1 and 2 of the post-crisis period in Columns (4) and (5), respectively are separated by a structural breakpoint, August 8, 2015, which is estimated by following Bai and Perron (2003). Moreover, a restriction that AUD, NZD, CAD, and CHF are not conditional on the regime is added into the model for a robustness check, and the results are shown in Columns (7) and (8). The *t*-tests on the difference term (6) and (9) are taken, and the null hypotheses are (5)–(4) = 0 and (8)–(7) = 0, respectively.

change on August 8, 2015, which matches the results in Columns (4) and (5). These results support the robustness of the Frankel–Wei model with a structural change.

3.2 Results of the exchange rate flexibility model

Here, the daily RMB rate in New York markets[3)] provided by Federal Reserve Economic Data was employed to proxy for the market-driven RMB rate (Dixon et al., 2016). Although Dixon et al. (2016) employed the Bank of China bid rate as the regulated RMB rate, this study chose the daily exchange rates in the Shanghai Interbank market to represent the entire Mainland China market regulated by the intervention of the monetary authorities. The relative volatility ratio on December 31, 2006 was set as the reference base.

Figure 1 displays the flexibility index as calculated by Eq. (2). Shortly after the RMB reforms in 2005, *Fle_index* surged from a low level (6.9 on August 19, 2005) to a high level (88.3 on September 1, 2005), showing a sharp increase in the exchange rate flexibility of Mainland China in the initial stage of the implementation of managed floating. After that, the index fluctuated within the range of 50 to 150 until the monetary authorities re-pegged RMB to the US dollar in 2008. From 2008 to 2010, the flexibility index experienced a two-year low (below 60 most of the time). After the RMB exchange rate regime switched from a dollar-peg to managed floating in June 2010, the flexibility index gradually returned to the level before the GFC. Moreover, at the end of 2013 when the PBOC dominated unilateral appreciation by raising the official rate to strengthen the RMB internationalization program, the flexibility index surged sharply and even exceeded 300. The above results for 2005–2013 are similar to those of Dixon et al. (2016), even though they chose the BOC bid rate as the regulated RMB rate. Moreover, the flexibility index supports the idea that central banks tend to lower exchange rate volatility in the domestic market to stabilize their domestic currencies under uncertain financial circumstances globally (He & McCauley, 2010).

Let us now concentrate on the period from 2014 to 2016, which was not included in Dixon

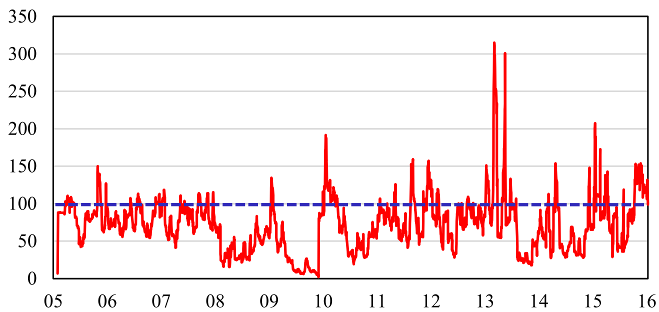

Figure 1. Exchange rate flexibility index for RMB

This figure displays the flexibility index calculated according to Eq. (3). The index=100 means the equality of RMB to the US dollar exchange rate flexibility between the Shanghai and New York markets.

et al. (2016). The flexibility index gradually increased from 24 on March 24, 2014 when the daily limit band expanded from ±1% to ±2%. However, it plunged in December 2014 and stayed at a low level until May 2015 when negotiations about RMB's inclusion in the SDR basket began. The flexibility index rose to about 200 following the RMB regime reforms in August 2015 and fell to about 30 in December 2015. In 2016, it first increased to about 150 and then began to fall in June. Overall, given that the degree of flexibility switched multiple times during the study period from 2005 to 2016, the MS framework is helpful to identify the possible regimes and regime-switching points for the PBOC's regulation of the RMB exchange rate.

The estimated results of the MS model in Table 3 provide evidence that the degree of flexibility varies markedly between the two regimes. As shown in Panel A of Column (1), in the high-flexibility regime, the constant coefficient $\alpha(s_t = 1)$ is 101.39; in the low-flexibility, the constant coefficient $\alpha(s_t = 1)$ is 39.38 (significant), thereby fulfilling the criterion that $\alpha(s_t = 1) > \alpha(s_t = 2)$. Therefore, Regime 1 and Regime 2 correspond to the situations when $s_t = 1$ and $s_t = 2$. The coefficient β is 0.98 (significant), showing the high persistence of the autoregressive effect. More-

Table 3. MS results for the flexibility index

	(1)		(2)	
Panel A: Regime varying coefficients				
	Regime 1	Regime 2	Regime 1	Regime 2
α	101.39***	39.38***	99.5***	37.96***
AR(1)	0.98***		0.98***	
LOG(SIGMA)	1.98***		1.98***	
EMP	—		−107.7***	
CDS_DIF	—		−0.01	
INT_DIF	—		0.91***	
Log Likelihood	−9858.83		−9848.69	
Panel B: Constant transition probabilities P(i, k) = P(s(t) = k | s(t−1) = i)				
P(1,1)	99.14%		99.13%	
P(1,2)	0.86%		0.87%	
P(2,1)	1.00%		0.99%	
P(2,2)	99.00%		99.01%	
Panel C: Constant expected duration (days)				
Regime 1	117		115	
Regime 2	100		101	
Panel D: Transition matrix parameters				
P11-C	4.75***		4.73***	
P21-C	−4.6***		−4.6***	

This table displays the estimated coefficients of an MS model of the flexibility index. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Columns (1) and (2) show the estimated results of the two possible forms of MS models, which are represented in Eq. (4) and Eq. (6), respectively.

over, Panel B shows the high regime dependence in both regimes: the probability of staying in the same regime is 99.14% and 99% for the high-flexibility (s_t = 1) and low-flexibility regimes (s_t = 2), respectively. Panel C shows the constant expected duration of the two regimes: 117 days in the high-flexibility regime and 100 days in the low-flexibility regime.

The estimated smooth regime probabilities shown in Figure 2 allow us to identify the regime-switching points. The highlighted parts in Panels A and B show the smooth regime probability of the high-flexibility and low-flexibility regimes, respectively. The high-flexibility probability from 2005 to 2008 supports that the domestic foreign exchange market enjoyed a flexible period with light regulation when China implemented managed floating. However, the re-pegging of RMB to the US dollar during the GFC caused a low-flexibility period from 2008 to 2010. After 2010, when China re-implemented managed floating, the low-flexibility regime continued until the end of 2012 despite the heavy regulation implemented in Q2 2012 to reduce the shock of the European debt crisis. From the end of 2012 to the end of 2014, the low-flexibility regime continued.

A high-flexibility regime arose in the first half of 2015. Figure 3 shows that the RMB

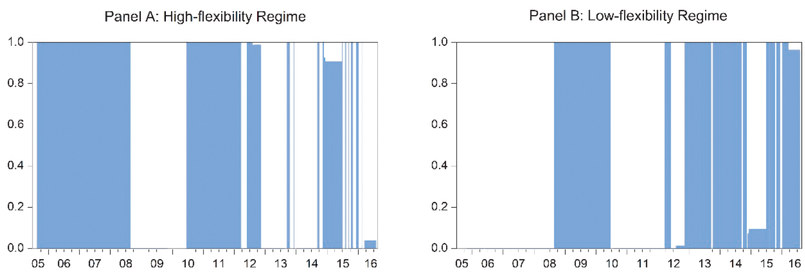

Figure 2. Smooth regime probabilities

The highlighted parts show the smooth probabilities of the high-flexibility regime in Panel A and of the low-flexibility regime in Panel B. These are estimated by using the standard MS model in Eq. (4).

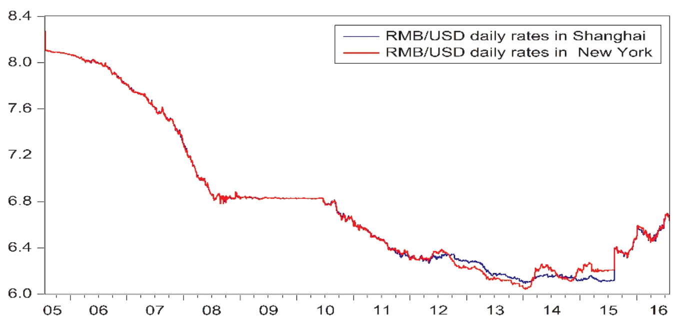

Figure 3. RMB/USD exchange rates

This figure shows the daily RMB/USD closing rates in the Shanghai Interbank market, representing regulated RMB rates, and the daily RMB/USD rates in New York, representing unregulated RMB rates. All data are collected from Reuters DataStream.

exchange rates both in domestic and in global markets were stable during this period, leading to a higher degree of flexibility compared with 2012–Q4 2014 when the global RMB rate was more flexible than the domestic RMB rate. From mid-2016, the degree of flexibility of RMB switched to a low-flexibility regime because RMB depreciated more markedly in the global market than in the domestic market.

Furthermore, the estimated result of the extended MS model shows that different market conditions between domestic and global markets (CDS_DIF and INT_DIF) and the scale of interventions calculated through official foreign reserves (EMP) can explain the exchange rate flexibility in the domestic market compared with the global market. Although these factors have the hypothesized signs, not all of them are significant, possibly because of the restrictions placed on cross-border capital flows in China. Moreover, the similar and significant estimated coefficients and transition matrix in the extended MS model prove the robustness of the MS framework for explaining the different adjustment processes of the degree of flexibility under the two regimes.

In summary, by employing the exchange rate flexibility model proposed by Dixon et al. (2016), the main findings are threefold. First, the degree of flexibility shows distinct adjustment processes under high-flexibility and low-flexibility regimes. Second, the Chinese monetary authorities reduced RMB exchange rate flexibility during the GFC (e.g., 2008–2010 and 2012) to eliminate shocks on the RMB exchange rate. Third, during the RMB depreciation from Q1 2014 (except in the first half of 2015), the monetary authorities restricted RMB flexibility to prevent sharp depreciation.

4. Conclusions and Implications

As stated by Levy-Yeyati and Sturzenegger (2005), identifying the *de facto* exchange rate regime demands the combination of exchange rate volatility and the volatility of exchange rate changes. In this study, I tried to reveal the *de facto* RMB foreign exchange rate regime during 2005–2016 from two perspectives: the implicit currency basket (Frankel & Wei, 1994, 2008) and the degree of flexibility (Dixon et al., 2016). Table 4 compares the estimated *de facto* RMB regimes with the *de jure* regimes that were officially announced.

The first finding of this study is that the so-called "*de facto* vs. *de jure*" problem existed in RMB exchange rate regimes. The *de facto* regime during the GFC was a dollar-peg rather than a *de jure*-managed floating regime with reference to a currency basket. Furthermore, the components of the implicit currency basket show that China implemented a crawling-peg regime rather than managed floating with reference to a currency basket in 2005–2008 and 2010–August 2015, as the US dollar's weight in the implicit currency basket is significantly near to unity (see the

Table 4. RMB foreign exchange rate regimes: *de facto* vs. *de jure*

<table>
<tr><th rowspan="2">Period</th><th rowspan="2">Date</th><th rowspan="2">de jure</th><th colspan="2">de facto</th></tr>
<tr><th>Implicit currency basket
(Frankel–Wei models)</th><th>Degree of flexibility
(MS models)</th></tr>
<tr><td>Pre-crisis</td><td>June 21, 2005–
July 15, 2008</td><td rowspan="4">Managed floating with reference to a currency basket.
(1) central parity rate
(2) daily trading band</td><td>Crawling-peg
(1) appreciation
(2) US dollar anchor</td><td>High</td></tr>
<tr><td>In-crisis</td><td>July 16, 2008–
June 18, 2010</td><td>Dollar-peg</td><td>Low</td></tr>
<tr><td rowspan="2">Post-crisis</td><td>June 19, 2010–
August 10, 2015</td><td>Crawling-peg
(1) appreciation
(2) US dollar anchor</td><td>High in 2010–Q4 2012;
low in Q4 2012–Q4 2014;
high in Q4 2014–Q3 2015</td></tr>
<tr><td>August 11, 2015–
July 29, 2016</td><td>Currency basket
(1) depreciation</td><td>Low</td></tr>
</table>

This table compares the *de facto* RMB foreign exchange rate regime announced by the monetary authorities with the *de jure* RMB foreign exchange rate regime evaluated from two perspectives: the implicit currency basket using Frankel–Wei models and flexibility regimes using MS models.

estimated results of the Frankel–Wei models in Table 2). This result supports the IMF's AREAER, which classifies RMB as a crawling-like currency. On the contrary, since August 2016, when RMB was reformed to be more market-based, the basket components are shown to be more diversified because of the clear decline in the US dollar's weight from 0.95 to 0.86, supporting the official announcement on August 11, 2016 that re-emphasized the reference to a currency basket.

Moreover, it is revealed that the monetary authorities adjusted their regulation on exchange rate flexibility according to real-world situations. For example, in the pre-crisis period from 2005 to 2008, the high-flexibility regime helped the development of the RMB exchange rate market, while the low-flexibility regime during the GFC from 2008 to 2010 helped reduce global shocks. In addition, the official announcement in 2010 concerning the implementation of a more flexible regime is supported by the high-flexibility regime from June 2010 to Q4 2012, although this regime only lasted for two years. Indeed, during the period of strong depreciation from Q4 2014 to Q3 2015, a high-flexibility regime arose for two possible reasons. First, the heavy interventional cost under strong depreciation restrained the monetary authorities' interventions, supported by the sharp decline in China's official foreign reserves. Second, political considerations meant that the PBOC retained a relatively flexible RMB to meet the IMF's requirements for RMB inclusion in the SDR. Since the regime reforms of August 2015, the low-flexibility regime has been implemented to relieve the sharp depreciation.

These findings suggest some implications for future RMB regime reforms. Although the RMB exchange market has been deregulated (e.g., daily trading bands have been expanded), the dominant weight of the US dollar in the implicit currency basket of RMB shows that the RMB rate still heavily depends on the US dollar, which would slow the process of RMB becoming a widely used global currency. Hence, a more diversified reference currency basket is needed if China wishes to continue to promote RMB internationalization in the future. Furthermore, it is appropriate for China to continue to prioritize RMB rate stability rather than structural reforms under uncertain external conditions such as the GFC and RMB depreciation. Hence, the deregulation of RMB flexibility in the RMB internationalization policy should be promoted under more stable circumstances in the future.

NOTES

1) Frankel and Wei (1994) proposed their implicit currency basket model based on monthly exchange rate data to reveal the "*de facto* vs. *de jure*" problem in East Asian currencies. This model has been widely used by other researchers to analyze RMB's exchange rate regime. Both Frankel and Wei (2008) and Frankel and Xie (2010) revised this model to a daily data-based model. Moreover, the selection criteria for the numeraire currency and structural change test (see also Zeileis et al., 2010) were mentioned in the revised model.
2) Frankel and Wei (1994, 2008) proposed selecting a remote, floating, and tradable currency as the numeraire. In the literature, the Swiss franc (Eichengreen, 2007; Frankel & Wei, 1994) and Canadian dollar (Yamazaki, 2006) have also been feasible selections. In addition, Ogawa and Shimizu (2006) used the trade-weighted average of the US dollar and euro as the numeraire of the Asian Monetary Unit. Additionally, the SDR was employed as the numeraire (Fang, Huang, & Niu, 2012; Frankel & Wei, 2008; Frankel & Xie, 2010). However, referring to the composition of the SDR basket, there should be multicollinearity when the SDR is used as the numeraire of RMB's reference currency basket.
3) Although Hong Kong is the largest offshore RMB market globally, the Hong Kong RMB to US dollar spot exchange rates market began in March 2011. Therefore, the daily spot RMB to US dollar exchange rate in New York published by the Federal Reserve is selected as the proxy for the offshore RMB exchange rate.

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Appendix 1. China's reforms of the RMB exchange rate since 2005

1994–2008	Dollar-peg regime.
2005, July	China revalued RMB against the US dollar by 2.1% and announced a switch from a dollar-peg regime to a managed floating regime based on market supply and demand, with reference to a currency basket. A ±0.3% daily RMB/USD trading band around the central rate, published by the PBOC as the official rate, is implemented in the interbank market.
2005, Aug	Governor Zhou revealed the components of the reference basket: the US dollar, yen, euro, pound sterling, Korean won, Singapore dollar, Malaysian ringgit, Russian ruble, Australian dollar, Thai baht, and Canadian dollar. Weights are secret.
2006, Dec	The method of deciding the central rate was reformed.
2007, May	China widened the daily trading band from ±0.3% to ±0.5%.
2008, Jul	China effectively re-pegged RMB to the US dollar by fixing the central parity rate.
2009, Jul	China launched its RMB internationalization program to allow RMB to become a global currency. It also began to permit domestic firms to settle in RMB in global trading.
2010, Jun	China announced the resumption of its exchange rate reforms of RMB and increased currency flexibility, heralding the end of the US dollar-peg in the GFC.
2012, Mar	China allowed all domestic firms to settle in RMB.
2012, Apr	China widened the daily trading band from ±0.5% to ±1%.
2014, Jan	RMB hit a record high of 6.04883 against the US dollar since the reform in 2005.
2014, Mar	China widened the daily trading band from ±1% to ±2%.
2015, Aug	China revalued RMB against the US dollar by -1.8% and announced a reform of the way in which the central rate is decided (mainly dominated by market makers' bid prices); it also re-emphasized the reference to a basket of currencies.
2015, Dec	It was decided that RMB would join the basket of the IMF's SDR with a 10.92% weight from October 2016.
2015, Dec	The CFETS Renminbi Index was launched with reference to a basket of currencies and details of the calculation method were published.

Source: PBOC