Estimating the Impact of China’s Central Bank Intervention on the RMB/US$ Exchange Rate Misalignment

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The paper studies the misalignment path of the RMB/US$ exchange rate, focusing on the managed floating period since July 2005 and determining the impact of the central bank’s intervention on the RMB/US$ misalignment. We adopt the permanent-and-transitory component decomposition approach developed by Gonzalo and Granger (1995) to estimate the equilibrium RMB/US$ rate and its misalignment within a vector error correction model (VECM). The sample for our study is the quarterly data on the exchange rate and some fundamental variables for the US and China between the 1st quarter of 2000 and the 2nd quarter of 2020. The results show a trend of the RMB/US$ reducing its undervaluation during the sample period, going from 41% to 35%. The government intervention substantially increased the RMB undervaluation, from an average of 5% to 39% without accounting for the weak exogeneity of the intervention, but to 25.8% after accounting for the exogeneity.

Keywords: equilibrium exchange rate, RMB/US$ exchange rate, RMB undervaluation, Chinese Yuan, foreign exchange intervention

INTRODUCTION

The misalignment of the Chinese currency, the renminbi (RMB), has been at the center of the debate surrounding bilateral and global trade imbalances for many years. Assessing the degree of currency misalignment is a motivation behind many studies that focus on the estimation of the equilibrium exchange rate. In the context of measuring the misalignment of the RMB, two unique characteristics in China’s foreign exchange rate regime must be taken into consideration simultaneously. First, the exchange rates of the RMB are tightly controlled by the Chinese government, which is reflected in two areas that directly or indirectly affect the RMB exchange rates: One, the RMB has not been fully convertible on a capital account. Any cross-border capital transactions must be approved or subject to regulations by various government authorities. Two, China’s central bank, the People’s Bank of China (PBoC), intervenes in the formation of the RMB exchange rates by setting the target rate, and the range of daily fluctuations, and by buying and selling the RMB and foreign exchanges in the market. The second characteristic of China’s foreign exchange regime is that it is not a static and fixed system. Government regulations have gone through many changes over time. These changes and their impacts on the dynamics of the exchange rate are much more significant in a transition economy like China.

The RMB exchange rate regime has experienced four important stages over the years: (1) Fixed-rate system under central planning economy (1949 – 1978); (2) Dual exchange rate system under economic reform (1979 – 1994); (3) Unified fixed-rate (1995 – 2005); (4) Managed floating (2005 –), in which the

RMB is pegged to a basket of currencies (mainly to the US dollar), based on the market forces of demand and supply.

From stage 1 to stage 4, the degree of government intervention and control shows a decreasing trend. It is a fair statement that the more government control/intervention, the less likely an exchange rate converges to its equilibrium level, and the more distorted the rate misalignment, and the less meaningful the estimate of the distorted misalignments. In *de facto* terms, many researchers still consider China a fixed rate regime around the beginning of the new century. In an exchange rate regime classification study, Levy-Yeyati & Sturzenegger (2005) designated China as a fixed-rate regime on both the 5-Way and 3-Way classification systems from 1987 up to 2004. Most of the studies on the RMB equilibrium exchange rate cover the periods before 2005, a few extending into part of stage 4. Partly due to the lack of recent data, few studies focus on the dynamics of the RMB exchange rate in stage 4, where the RMB has entered a managed floating regime.

The recent designation of “currency manipulator” by the US Treasury, the ensuing firm rejection by the People’s Bank of China, and the evolving dynamics of China’s foreign exchange regime all beg the question: is the Chinese currency undervalued or overvalued, and if it is, by how much, and in what period? Since market price always fluctuates around its equilibrium level, overvaluation or undervaluation of a currency is common even in a free-floating exchange market. A much more important underlying question, therefore, is, to what extent is the RMB misalignment, if exists, due to its central bank’s intervention?

The current paper seeks to complement the existing literature on the equilibrium exchange rate of the RMB by addressing these questions. We intend to depict the dynamic path of the RMB misalignment against the US dollar when the managed floating started to assume true meaning in China, especially after the foreign exchange reform in July 2005. By incorporating the PBoC intervention explicitly in the study, we intend to examine to what extent the government intervention has contributed to the RMB/US$ exchange rate misalignments in recent decades.

LITERATURE REVIEW

The concept of the equilibrium exchange rate is based on two categories of theories or models: the purchasing power parity (PPP) and structural models involving theoretical relationships of fundamental economic variables. The PPP theory believes the equilibrium exchange rate is determined by the relative prices between the countries. This approach is still applied by many researchers, either in its original format or in some extended form where the Balassa-Samuelson effect and other economic variables are incorporated. See, e.g., Frankel (2005), Coudert & Couharde (2007), Cheung et al. (2007), Cheung et al. (2010). The estimation results range widely from little evidence of the RMB undervaluation to small undervaluation (5%) to large undervaluation (49%). The deficiency of the PPP as a foundation for measuring the equilibrium exchange rate lies in the fact that the law of one price, all goods are tradable and other assumptions underlying the PPP may not hold in practice.

Recent examples of structural models include the Fundamental Equilibrium Exchange Rate approach (FEER) popularized by Williamson (1985) and the Behavioral Equilibrium Exchange Rate approach (BEER) developed by Clark & MacDonald (1999) and MacDonald (2000). The estimated misalignments of the RMB exchange rate using the FEER approach also vary widely from small overvaluation, small undervaluation to large size undervaluation (40%) for different periods (Wang, 2004; Coudert & Couharde, 2007; Goldstein, 2004; Cline & Williamson, 2009; 2012).

Contrary to the FEER approach, the BEER approach advocated by Clark & MacDonald (1999) and MacDonald (2000) does not define and estimate an equilibrium position of internal and external balance. Instead, it focuses on modeling the actual behavior of real exchange rates as stably influenced by the dynamics of the fundamental variables in the statistical sense. In this context, using the econometric method of cointegration for estimating the long-run equilibrium exchange rates seems to have been pioneered by Elbadawi (1994). The empirical studies on the RMB misalignment using the BEER approach range from almost no undervaluation (Wang, 2004) to as high as 59% undervalued (Bénassy-Quéré et al., 2006) for different estimating periods. Similar studies include Coudert & Couharde (2007), Jongwanich (2009), and Gan et al. (2013).

Most of the studies on the equilibrium RMB exchange rate and its misalignment either leave out or are not focused on the unique role of the central bank's intervention. Some studies evaluate the effectiveness of the central bank's intervention on the RMB fluctuations and suggest a rule-based intervention has stronger stabilization power than a discretional intervention (Wang and Deng 2016). Some investigate how the PBoC can use its policy communication channel to guide RMB market expectations and reduce volatility, and assess its effectiveness (Liu & Ding, 2019; Lu & Sun, 2017). Some study the interaction between the central bank intervention, expected RMB exchange rate, and short-term international capital flow (Yang & Feng, 2020); still, others examine the issue of 'fear of appreciation' in asymmetric intervention. e.g., Wang et al. (2020) find that the PBoC's tolerance level for appreciation is much higher than that for depreciation and it responds more vigorously to substantial appreciation than to depreciation. Although all these studies examine the central bank intervention, they focus on its impact on the actual rate fluctuations. Very few studies, if any, have estimated the central bank's impact on the RMB equilibrium level and the intervention impact on the degree of its misalignment. To our knowledge, the only studies that are close to our research are by Chen (2013), who finds that the central bank intervention contributed to the RMB exchange rate's approaching its equilibrium level most of the time after 2005, and Liu, Jiang, and Tang (2016), who show that the PBoC intervention has expected effects on the RMB misalignment, i.e., its purchase of foreign reserve is related to the RMB undervaluation while its sale to overvaluation in the period after 2005.

The significance of the current study is highlighted by the following facts: (1) The Chinese foreign exchange regime is an evolving and dynamic process. Previous studies were carried out for different time periods before the real managed floating regime accumulated a reasonable size of data. Our study tries to extend the sample size to focus on the misalignment path during the managed floating period after 2005. (2) Few studies on the RMB misalignments in the literature have focused on the government intervention's impact. Although Liu et al. (2016) identify an expected correlation between the central bank intervention and the RMB misalignment, no effort is attempted for measuring the extent of the relationship. Our study tries to quantify the impact of the central bank intervention on the RMB/US$ misalignments. (3) Methodologically, we believe our study is the first effort to apply the Gonzalo and Granger decomposition (Gonzalo & Granger, 1995) in estimating the RMB equilibrium exchange rate and its misalignments, and the general procedure is simplified in comparison with the common practice. We hope our study will shed some light on the current issues surrounding the RMB undervaluation and its implication involving China's bilateral and global trade imbalances.

The rest of the paper is organized as follows: the next section introduces the model and the econometric approach underlying the estimation method; Section 4 presents and discusses the estimation results; finally, we draw some conclusions in Section 5.

THE MODEL AND ECONOMETRIC PROCEDURES

Our study adopts the BEER approach that is popularized by Clark & MacDonald (1999) and MacDonald (2000) due to its various advantages. We choose the following fundamental variables in our estimation model: relative productivity (*bs*), terms of trade (*tot*), net foreign assets (*nfa*), net exports (*nx*), and foreign exchange reserves (*fx*). The first three variables are included in almost all structural models of the equilibrium exchange rate studies. The last two variables are important in the context of China, where the government trade and currency policy insert frequent influences on the dynamics of the RMB exchange rate. We do not include interest rate differential for several reasons: One, the interest rate differential, in general, affects the exchange rate in the short run, it is less relevant in affecting the long run, equilibrium exchange rate; Two, the interest parity condition is not validated well in general (Lewis, 1995). It has not been very successful empirically at predicting exchange rate movements (Driver & Westaway, 2005); A final fundamental factor is the official foreign exchange reserve, which in general serves as a measure of government intervention in the foreign exchange market. The change in the official reserves or the central bank's net foreign asset position, therefore, is commonly used as a proxy to measure foreign exchange intervention (Adler et al., 2015; Zhang & Pan, 2004). Therefore, we assume the RMB exchange rate to be determined by a fundamental vector defined as follows:

$$q_t = f(bs_t, nfa_t, tot_t, nx_t, fx_t) \tag{1}$$

where all terms are in logarithm (except *nx*) and the fundamentals are in ratio (except *nx* and *fx*) of China to the US values.

We follow Clark & MacDonald (2004) to adopt the Gonzalo & Granger (1995) decomposition (G-G) approach in a VECM formation. For a *p*-order VAR system with an *n*-element vector x_t, a VECM has the following expression:

$$\Delta x_t = \alpha\beta' x_{t-1} + \sum_{i=1}^{\infty} \Gamma_i \, \Delta x_{t-i} \; + \varepsilon_t, \tag{2}$$

where: δt is an $n\times 1$ vector of time trends; Γ_i is a short-run impact matrix that captures short-run deviations from the equilibrium. α and β gives a measure of the long-term impacts of the deviations from the system equilibrium. The cointegrating vector β measures the way the elements of x_t group together to form a stationary linear relationship. α measures the adjusting speed for the system to move back to the common trend when deviations occur. Gonzalo & Granger show that the dynamics of x_t can be interpreted as driven by two types of forces: one is the permanent components that are driven by some common stochastic trends f_t consisting of a smaller number ($k = n - r$) of I (1) x_t; another is I (0) transitory components $\tilde{x}_t$:

$$\underset{n\times1}{x_t} \; = \; \underset{n\times k}{A_1} \, \underset{k\times1}{f_t} \; + \; \underset{n\times1}{\tilde{x}_t} \, . \tag{3}$$

The construction of the permanent components $A_1 f_t$ is through identifying the common trends f_t, which is in turn made possible by assuming that f_t is a linear combination of the observable variables x_t: $\underset{k\times1}{f_t} = \underset{k\times n}{B_1} \, \underset{n\times1}{x_t}$, and that the transitory components do not have lasting effects on the permanent components. The latter assumption makes sense in the equilibrium exchange rate context. If we consider transitory innovations to only have a temporary impact on the changes of the equilibrium rate, but not on its level, any lasting effects they might have could be interpreted as being incorporated into and estimated as, the equilibrium value. Relating to ECM (2), Gonzalo & Granger show that the only linear combination that meets the above assumptions is $f_t = \alpha'_\perp x_t$. This results in the permanent-transitory decomposition formula:

$$A_1 f_t = \beta_\perp (\alpha'_\perp \beta_\perp)^{-1} \alpha'_\perp x_t \; \Rightarrow \; Permanent\ Components, \tag{4}$$

$$\tilde{x}_t = \alpha(\beta'\alpha)^{-1}\alpha' x_t \Rightarrow Transitory\ Components. \tag{5}$$

Although Gonzalo & Granger provide the estimation and testing procedure for $\alpha_\perp$, the actual derivation is already embedded in the Johansen (1988) procedure for estimating ECM (2), whose eigenvector solution gives the estimation of β. Similarly, for $\alpha_\perp$, it comes down to solving the eigenvalue problem:

$$\left|\lambda S_{00} - S_{01} S_{11}^{-1} S_{10}\right| = 0, \tag{6}$$

to derive the eigenvalues $\hat{\lambda}_1 > \cdots > \hat{\lambda}_n$, and the eigenvectors $\widehat{M} = (\widehat{M}_1, \cdots, \widehat{M}_n)$, normalized such that $\widehat{M}' S_{00} \widehat{M} = I$. $\hat{\alpha}_\perp$ will be the last ($n - r$) eigenvectors in $\widehat{M}$.

ESTIMATION RESULTS

VECM Model Specification

The Augmented Dicky-Fuller unit root tests in Table 1 proved the existence of the unit root. It also shows that taking the first difference has transformed all variables from nonstationary I (1) to stationary I (0) processes. Since there is an indication of structural breaks in these series, we also applied the Lumsdaine-Papell (L-P) and Lee-Strazicich (L-S) unit root tests. The former is a generalized Zivot-Andrews test, the latter a Schmidt-Phillips test, both allow for more than one break in the trend. In Table 2, the L-P tests again confirmed all series are I (1) in levels. The first differencing rendered only some series stationary but *q*, *bs*, and *nfa* still contain the unit root in the first differences according to the L-P tests. However, based on the L-S tests, the first differencing generated a stationary process for all series.

TABLE 1
THE AUGMENTED DICKY-FULLER UNIT ROOT TEST

var	intercept/trend	lags†	ADF	1%	5%	10%	H_0
q	intercept	3	-1.259	-3.514	-2.898	-2.586	Accept
D_q		2	-3.459	-3.517	-2.899	-2.587	Reject
bs	none	3	-1.172	-2.592	-1.944	-1.618	Accept
D_bs		2	-3.544	-2.595	-1.945	-1.614	Reject
tot	none	1	-0.996	-2.592	-1.944	-1.618	Accept
D_tot		0	-5.946	-2.594	-1.945	-1.614	Reject
nfa	intercept	2	-1.827	-3.513	-2.898	-2.586	Accept
D_nfa	none	1	-3.457	-2.595	-1.945	-1.614	Reject
fx	intercept+trend	1	-0.764	-4.074	-3.465	-3.158	Accept
D_fx		0	-5.911	-4.077	-3.467	-3.160	Reject
nx	intercept	0	-2.651	-3.511	-2.897	-2.585	Accept
D_nx	none	1	-8.005	-2.595	-1.945	-1.614	Reject

† Lag selection by the general-to-specific method.
Source: Author calculation.

TABLE 2
THE LUMSDAINE-PAPELL*/ LEE-STRAZICICH UNIT ROOT TESTS

var	**breaks**	**lags**[†]	***t***	**1%**	**5%**	**10%**	H_0	***Test***[‡]
q	2 in intercept	3	-4.124	-6.740	-6.160	-5.890	Accept	L-P
D_q		2	-4.951				Accept	
D_q		1	-7.181	-6.691	-6.152	-5.798	Reject	L-S
bs	2 in intercept	3	-4.220	-6.740	-6.160	-5.890	Accept	L-P
D_bs		2	-5.129				Accept	
D_bs		1	-7.172	-4.073	-3.563	-3.296	Reject	L-S
tot	2 in intercept	1	-4.607	-6.740	-6.160	-5.890	Accept	L-P
D_tot		0	-6.961				Reject	
D_tot		0	-6.471	-4.073	-3.563	-3.296	Reject	L-S
nfa	2 in intercept	2	-4.571	-6.740	-6.160	-5.890	Accept	L-P
D_nfa		1	-6.095				Accept	
D_nfa		2	-4.254	-4.073	-3.563	-3.296	Reject	L-S

fx ***D_fx***	2 in intercept & trend	1 0	-4.529 -8.034	-7.190	-6.750	-6.480	Accept Reject	L-P
D_fx		0	-7.242	-6.821	-5.917	-5.541	Reject	L-S
nx ***D_nx***	2 in intercept	0 1	-5.758 -9.362	-6.740	-6.160	-5.890	Accept Reject	L-P
D_nx		0	-6.322	-4.073	-3.563	-3.296	Reject	L-S

* Generalizes the Zivot-Andrews test to allow for more than one break in the trend.
† Lag selection by the general-to-specific method.
‡ L-P: The Lumsdaine-Papell unit root test; L-S: The Lee-Strazicich unit root test.
Source: Author calculation.

For the lag determination of the unrestricted VAR system, the results from all the criteria in Table 3 do not have a consensus. While Schwarz information and Hannan-Quinn information criteria suggest lag 1, all other criteria suggest lag 7. Although (Lütkepohl 2005) shows that Hannan and Quinn's information criterion (HQ) and Schwarz's Bayesian information criterion (SC) statistics provide consistent estimates of the true lag length, while the FPE and AIC overestimate in infinite samples, we are still left with no clear guidance in this finite sample situation. We, therefore, resort to the residual check. The autocorrelation and normality tests for the residuals from the VAR system with different lags suggest that the optimal choice seems to be lag 3. We, therefore, take a lag of 3 for the VAR specification, which implies a VEC model with a lag of 2.

TABLE 3
LAG LENGTH DETERMINATION FOR VAR

LAG	LOGL	LR	FPE	AIC	SC	HQ
0	1482.226	NA	1.40e-24	-37.90068	-36.61264	-37.38591
1	2047.276	936.7934	1.28e-30*	-51.82304	-49.43098*	-50.86706*
2	2083.577	54.45162	1.33e-30	-51.83097	-48.33487	-50.43376
3	2120.058	48.96220	1.43e-30	-51.84364	-47.24351	-50.00521
4	2156.999	43.74567	1.62e-30	-51.86840	-46.16424	-49.58874
5	2208.526	52.88314*	1.37e-30	-52.27701	-45.46881	-49.55613
6	2253.141	38.74446	1.57e-30	-52.50372*	-44.59149	-49.34161

* Indicates lag order selected by the criterion.
LR: Sequential modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion.
Source: Author calculation.

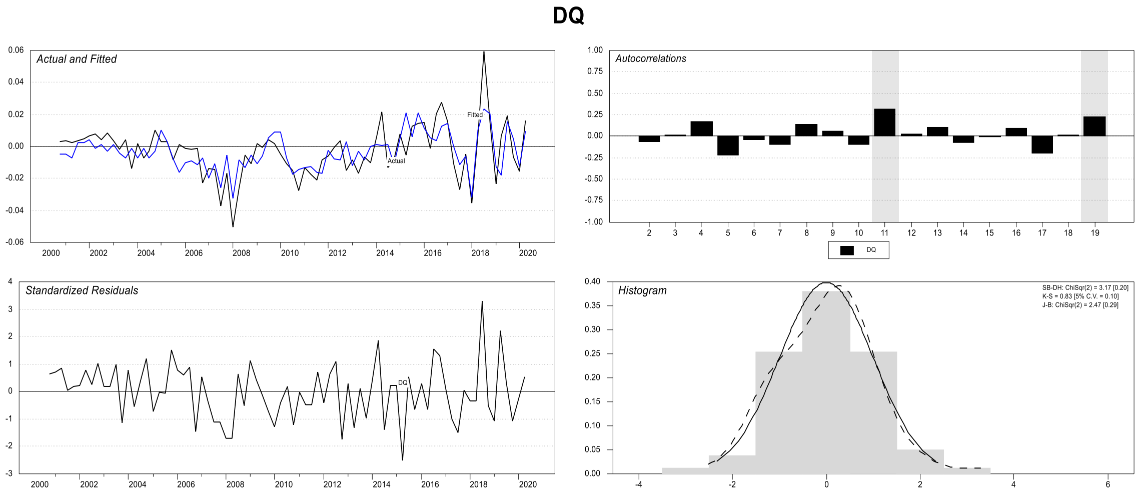
Before testing for the cointegration rank, we make sure the model is reasonably well specified by conducting the residual analysis of the unrestricted model. The results in Table 4 show that autocorrelation is a borderline case. The null of no ARCH is accepted but normality for the system is rejected. However, a closer look at the individual equations in the VECM system in Table 5 reveals that the nonnormality is mainly caused by *Dnfa* and *Dfx* equations. For our focus, the exchange rate equation *Dq*, the null of normality is accepted. The plot and statistics in Figure 1 confirmed the normality null by the SB-DH test statistic (Doornik & Hansen, 1994; Shenton & Bowman, 1977) of 3.17 with a *p*-value of 0.20, and the Jarque-Bera test statistic of 2.47 with a *p*-value of 0.29.

TABLE 4
RESIDUAL DIAGNOSTIC TESTS

H0	Stat	Prob.
No Autocorrelation	LM (1): $\chi^2(36) = 52.017$ LM (2): $\chi^2(36) = 51.510$	0.041 0.045
Normality*	$\chi^2(12) = 29.067$	0.004
No ARCH	LM (1): $\chi^2(441) = 479.019$ LM (2): $\chi^2(882) = 924.836$	0.103 0.154

* The Doornik-Hansen test, see (Doornik and Hansen 1994).
Source: Author calculation.

FIGURE 1
RESIDUAL DIAGNOSTICS OF THE EXCHANGE RATE EQUATION IN VECM*



Source: Author estimation.

TABLE 5
RESIDUAL STATISTICS OF VECM EQUATIONS

	Mean	*Std.Dev*	*Skewness*	*kurtosis*	*Maximum*	*Minimum*
DQ	0.000	0.010	0.119	3.101	0.028	-0.025
DBS	0.000	0.013	-0.056	3.367	0.037	-0.040
DTOT	0.000	0.002	0.814	5.254	0.009	-0.006
DNFA	-0.000	0.000	0.406	5.165	0.001	-0.001
DNX	-0.000	0.008	-0.282	3.347	0.020	-0.026
DFXR	-0.000	0.000	0.510	4.331	0.001	-0.001

	ARCH (3)	**Normality**	**R-Squared**
DQ	1.928 [0.588]	0.778 [0.678]	0.608
DBS	0.646 [0.886]	1.839 [0.399]	0.563
DTOT	0.050 [0.997]	11.388 [0.003]	0.376
DNFA	8.795 [0.032]	15.013 [0.001]	0.599
DNX	1.765 [0.623]	2.053 [0.358]	0.428
DFXR	9.975 [0.019]	7.279 [0.026]	0.564

Source: Author calculation.

The cointegration rank test is notoriously sensitive to the specification of the deterministic terms in the VEC model even after an optimal VAR lag is chosen. Depending on whether a trend or constant term or both are restricted in the cointegration relations, different asymptotic tables for the critical values have to be used, (see (Juselius 2006). Since our model includes structural breaks and dummies, we have to simulate the asymptotic distribution of the trace test statistic to generate the critical values. The results in Table 6 show a rank of 1, suggesting one cointegration relation in the system. This is reinforced by examining the roots of the companion matrix.

TABLE 6
SIMULATED ASYMPTOTIC TRACE TEST FOR COINTEGRATION RANK (r)

p-r	**r**	**Eig.Value**	**Trace**	**Trace***	**Frac95**	**P-Value**	**P-Value***
6	**0**	0.402	149.162	107.426	99.590	0.000	0.013
5	**1**	0.357	108.520	75.960	77.103	0.000	0.061
4	**2**	0.282	73.615	49.827	56.407	0.001	0.164
3	**3**	0.219	47.402	29.261	38.123	0.004	0.317
2	**4**	0.191	27.858	16.355	23.275	0.011	0.319
1	**5**	0.131	11.066	9.666	11.557	0.058	0.102

* The Bartlett small sample corrections.
Source: Author calculation.

Setting the rank to 1 and estimating the VECM generate the cointegrating vector (normalized on the exchange rate *q*) as reported in Table 7.

TABLE 7
ESTIMATED COINTEGRATING AND ADJUSTMENT VECTORS

Cointegrating Vector (β)							
q	*bs*	*tot*	*nfa*	*nx*	*fx*	*Ds053*	*C*
1.000	-0.267	-9.475	7.265	-3.051	-16.333	0.297	-1.734
(.NA)	(-1.181)	(-2.862)	(0.541)	(-1.794)	(-1.641)	(3.161)	(-13.437)
Adjustment Vector (α)							
var	*Dq*	*Dbs*	*Dtot*	*Dnfa*	*Dnx*	*Dfx*	
coeff	-0.042	0.105	-0.001	-0.000	0.021	0.000	
t	(-2.880)	(5.528)	(-0.336)	(-0.316)	(1.592)	(1.156)	

* t-stat in parenthesis. *Dx* denotes the first difference of the *x* variable.
Source: Author calculation.

Table 7 implies the following cointegration relation (with t stats in parenthesis):

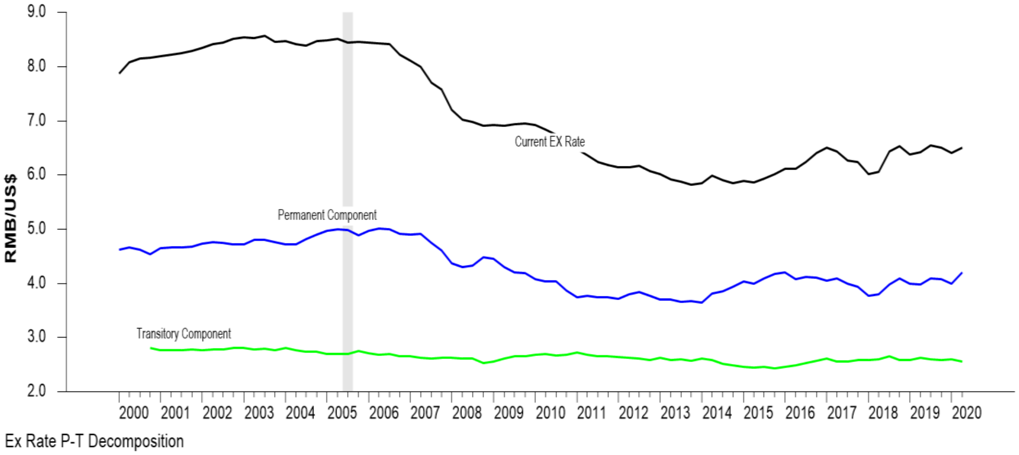
$$q = \underset{(1.181)}{0.267bs} + \underset{(2.862)}{9.475tot} - \underset{(0.541)}{7.265nfa} + \underset{(1.794)}{3.051nx} + \underset{(1.641)}{16.333fx} - \underset{(-3.161)}{0.297Ds053} + \underset{(13.437)}{1.734} \tag{7}$$

The coefficients on *fx* and *nfa* are in the expected sign, but the signs for *bs*, *tot*, and *nx* are unexpected, although all but *tot* are insignificant. The unexpected signs may be due to the difference between the short-run effects and long-run effects or an issue of remaining simultaneity in the system. Since our focus here is not on the estimation of individual coefficients but derive the permanent components from the cointegrating system, this issue is less of a concern for us. The first alpha coefficient -0.042 in the adjustment vector corresponds to the exchange rate equation *Dq* in the system. Its negative sign is expected and significant, implying the system moves back to its long-run equilibrium when there are deviations. However, the adjustment process appears to be slow. The size of 0.042 implies that the system only adjusts 4.2% each quarter towards its long-run equilibrium level from its previous quarter's deviation. At that pace, it would take 23.8 quarters, or about 6 years for the RMB/US$ exchange rate to move back to its equilibrium, absent new shocks, or interventions.

Decomposition and Misalignment

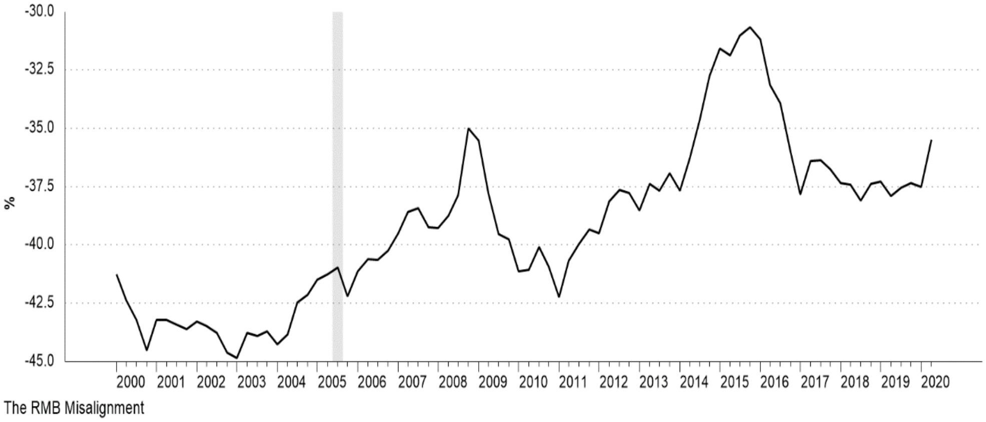
Based on the G-G decomposition Eq.(3) and its connection with the estimated VECM, the actual real RMB/US$ exchange rate is decomposed into the permanent and transitory components as shown in Figure 2. The RMB misalignment for the entire sample period is depicted in Figure 3.

FIGURE 2
RMB/US$ RATE DECOMPOSITION



Source: Author estimation.

FIGURE 3
THE RMB MISALIGNMENT PATH



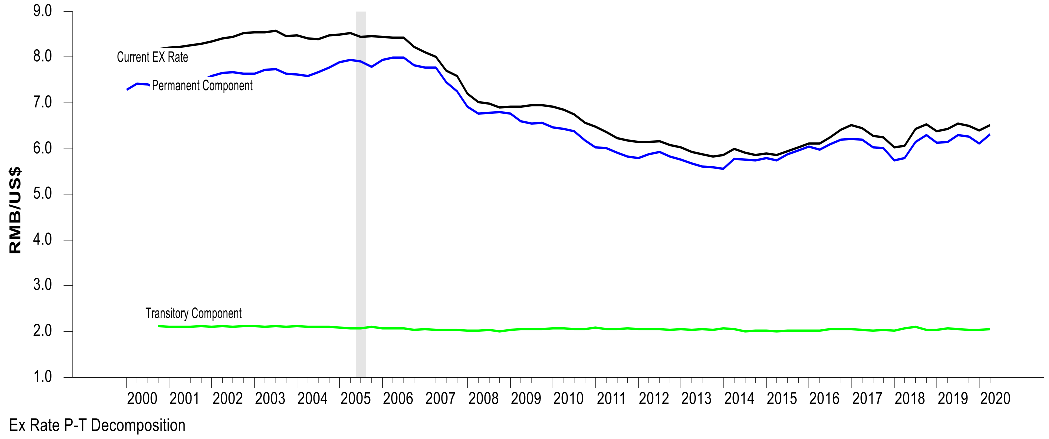
Source: Author estimation.

Figure 3 shows the general trend of the RMB reducing the size of undervaluation against the US$. The undervaluation has gone from 41% in 2000Q1 to 35% towards the end of the sample period. The switch to the managed floating regime after 2005Q3 has given the RMB much more flexibility to float, which resulted in a continuous appreciation against the US dollar, especially during the Great Recession period of 2007-2009. This caused the RMB to knock off more than 14% of its previous undervaluation against its equilibrium level. After a brief period of reversing the trend, the RMB went back to the same undervaluation size (42.5%) as that of the beginning of 2000. But after 2011Q1, an episode of stronger appreciation in its equilibrium level reduced undervaluation, to a size of 31% towards 2016Q1. The RMB then saw a big reverse in the following year before it resumed the path of shrinking undervaluation in 2018Q4. By the second quarter of 2020, the RMB is still undervalued by 35~36%.

The Role of the PBoC Intervention

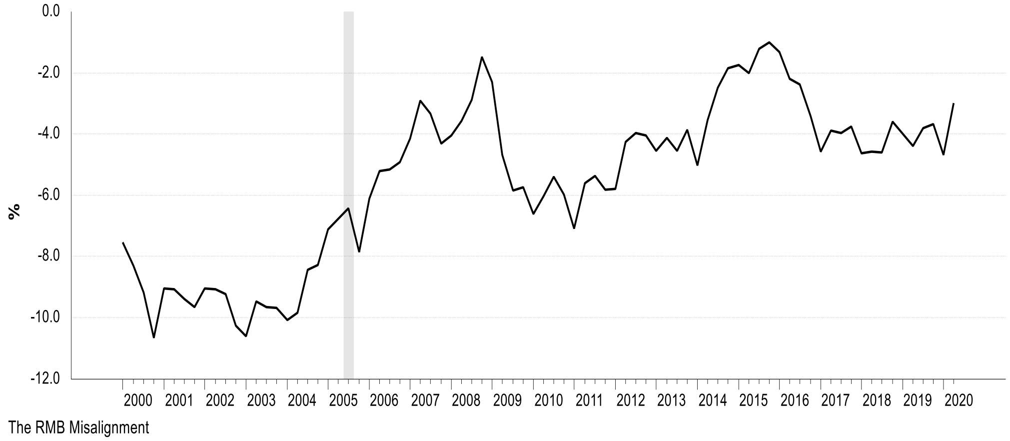
To estimate to what extent the PBoC's intervention has influenced the RMB misalignment, we re-estimate the equilibrium exchange rate and its misalignments without China's foreign exchange reserves, *fx*, in the system. If both models are specified and estimated properly, the difference in the misalignments should indicate the impact of the PBoC's intervention in the RMB/US$ exchange rate dynamics. The results are presented in Figure 4 and Figure 5.

FIGURE 4
THE RMB/US$ DECOMPOSITION WITHOUT THE PBOC INTERVENTION



Source: Author estimation.

FIGURE 5
THE RMB MISALIGNMENT WITHOUT THE PBOC INTERVENTION

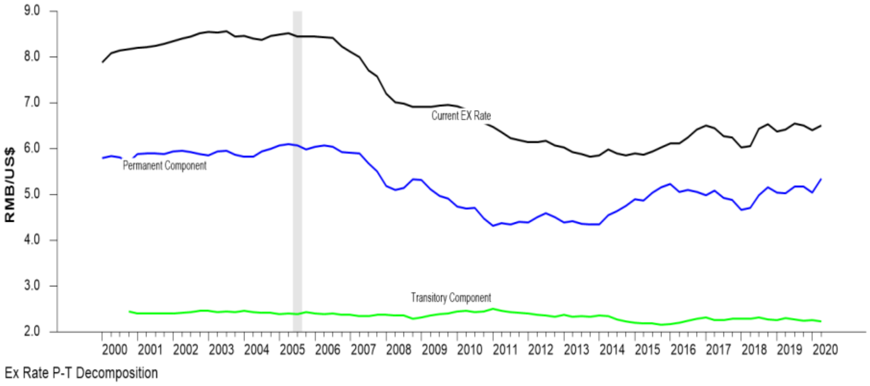


Source: Author estimation.

The RMB misalignment pattern without the PBoC intervention in Figure 5 is similar to that with the intervention shown in Figure 3. The overall trend is shrinking undervaluation and the trend is marked by similar temporary ups and downs at the same points in time as in Figure 3. Larger flexibility is evident after 2005Q3. The only difference is the size of the undervaluation. The RMB undervaluation without the PBoC intervention ranges from 10.7% to 1%, averaging 5.5%, much smaller than that with the intervention, which ranges from 45% to 31%, averaging 39%. This seems to suggest that if no active foreign exchange market intervention is present the RMB/US$ equilibrium value would be much lower for the RMB. The estimated RMB undervaluation would be much smaller. The fact that the introduction of the intervention has caused the undervaluation to be greater, not to be smaller or to be reversed to overvaluation, suggests strongly that the PBoC has intentionally kept the RMB to be undervalued against the US$ over the years, even after the managed floating period since 2005Q3. Only more flexibility after that has allowed the RMB to appreciate more, shrinking the size of the undervaluation.

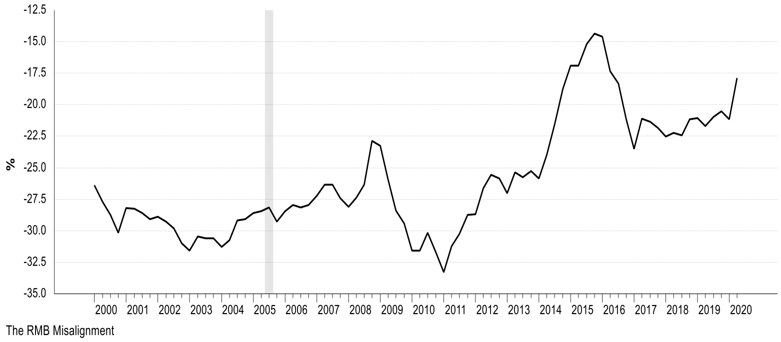
One more perspective is that, as an autonomous policy variable, China's foreign exchange reserve position may not be strongly affected by other fundamental variables in the system. It is therefore interesting to check the weak exogeneity of *fx* and factor this into our estimation. The LR test statistic of $\chi^2(1)$=0.537 with a *p*-value of 0.464 shows that *fx* is indeed weakly exogenous. The Granger causality tests in our VAR system also show that the null of non-causality from *fx* to q is rejected [$\chi^2(5)$=11.870, *p*=0.037]; but that from q to *fx* is accepted [$\chi^2(5)$=5.870, *p*=0.319]. The estimation results after treating *fx* as weakly exogenous are presented in Figure 6 and Figure 7.

FIGURE 6
THE RMB/US$ DECOMPOSITION WITH A WEAKLY EXOGENOUS fx



Source: Author estimation.

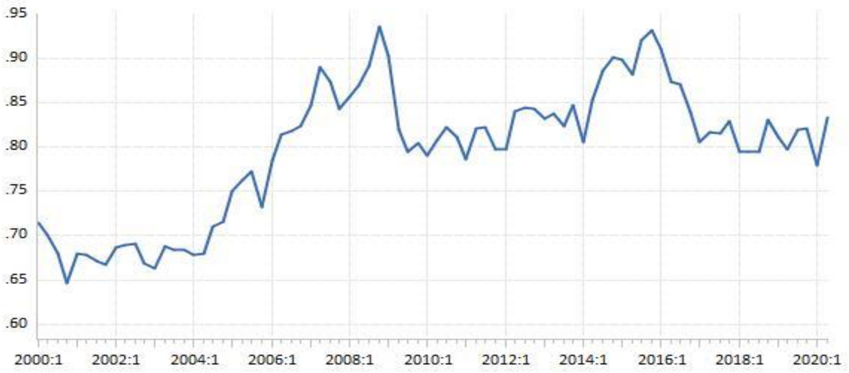
FIGURE 7
THE RMB MISALIGNMENT WITH A WEAKLY EXOGENOUS FX



Source: Author estimation.

Figure 7 shows that the general pattern of the RMB misalignment is quite similar to that shown in Figure 3 where no account of *fx*'s exogeneity is taken. The overall trend is a reduction of the size of undervaluation against its equilibrium level. However, the size of the undervaluation throughout the whole period is smaller than shown in Figure 3, going from 31% in 2000Q1 to 18% towards the end of the sample period. Using Figure 7 to compare with Figure 5 to assess the role of the PBoC's intervention, we can draw the same conclusion that the PBoC has intentionally kept the RMB to be undervalued against the US$ over the years, including the managed floating period after 2005Q3. The undervaluation has gone from an average of 5.5% to 25.8% due to the intervention. However, it did allow for more flexibility in the RMB regression to its long-term equilibrium level. If we compare the RMB misalignment with and without *fx* and take the percentage difference as an impact indicator of the PBoC's intervention, we can estimate the degree of the impact and its pattern. This is presented in Figure 8, which shows how much the RMB undervaluation would have shrunk if no intervention were present. For example, in the 1st quarter of 2000, the RMB undervaluation would have shrunk by 71% from its estimated misalignment without the intervention. There is clearly a regime shift in 2005. The average impact is 69% before 2005Q3 but 84% after. The pattern suggests that after China's foreign exchange regime entered the managed floating stage, the monetary authority has more relied on market intervention to keep the exchange rate within its desired range. The force of intervention has remained relatively stable after 2005Q3 except for two periods, 2008Q4~2009Q1 and 2015Q4~2016Q1. The first period is the Global Recession and the second is related to a turmoil period when the tumbling oil price coupled with the PBoC's three consecutive devaluations of the RMB, knocking over 3% off its value.

FIGURE 8
THE PATTERN OF THE PBOC INTERVENTION IMPACT ON THE EQUILIBRIUM RMB



Source: Author estimation.

CONCLUSIONS

In this study, we have examined the RMB/US$ exchange rate misalignment path by focusing on the managed floating period after 2005Q3. We adopted the Gonzalo & Granger (G-G) decomposition (Gonzalo & Granger, 1995) to directly estimate the equilibrium value of the RMB/US$ in the framework of a cointegrated vector error correction model (VECM).

Our study shows a general trend of the RMB reducing the size of undervaluation against the US$ throughout the years from 2000Q1 to 2020Q2. The RMB undervaluation has gone from 41% in 2000Q1 to 35% towards the end of the sample period. The switch to the managed floating regime after 2005Q3 has provided more flexibility to the RMB, particularly during the Great Recession period of 2007-2009. The largest undervaluation (44.85%) was observed in 2003Q1. By the second quarter of 2020, the RMB was undervalued by 35~36%.

We also try to separate the PBoC's intervention in the foreign exchange market and estimate its impact on the RMB misalignments. The estimated results show that the general pattern of the RMB misalignment with and without the PBoC intervention is similar. The overall trend is shrinking undervaluation and marked by similar temporary ups and downs, with larger flexibility after 2005Q3. However, the PBoC intervention did increase the size of the RMB/US$ undervaluation, from an average of 5.5% to an average of 39%. This indicates that the RMB/US$ undervaluation would be much smaller without the PBoC's active foreign exchange market intervention.

Estimation after accounting for the weak exogeneity of China's foreign exchange intervention also confirms the general pattern. Again, the overall trend is a reduction of the size of the RMB/US$ undervaluation against its equilibrium level. The PBoC intervention causes the RMB/US$ undervaluation of 14.4% to 33.3% (averaging 25.8%) through the sample period. Using the RMB misalignment difference with and without the PBoC intervention as an impact indicator of the PBoC's intervention, we show the degree of the impact averages 69% before 2005Q3 but 84% after.

The practical implication of our study is interesting. On the one hand, the PBoC has enhanced its intervention in the RMB/US$ rate even after the managed floating period since 2005Q3. On the other hand, the intervention has increasingly relied on market forces to keep the RMB rate within the desired range, therefore allowing more flexibility and has shrunk the size of the RMB/US$ undervaluation over the years. This may turn out to be a sound and practical approach for a central bank to manage its exchange rate policy in countries like China.

The PBoC's intervention is an integral part of the foreign exchange dynamics. An estimation of the long-run equilibrium exchange rate of RMB/US$, or any rates against the RMB, must incorporate a measure of the intervention. Since the RMB misalignment depends on the estimation of the intervention, which is measured by the official exchange reserves, we must be careful in interpreting the exact impact value of the PBoC's intervention on the RMB/US$ misalignment. The change in the official reserves could be the result of several factors including current account transactions, capital flows, monetary authority's interest income, and the central bank's policy intervention. A better measure of the central bank's intervention would be to take into consideration of the net change in the foreign exchange dealer banks' settlement and sales accounts and note the difference between that and the total change in the central bank's foreign currency assets. However, the dealer banks' settlement and sales accounts data from China's State Administration of Foreign Exchange only starts from 2010 M1. The limited data would substantially reduce our sample size. We hope that future studies could apply different measures of the intervention when enough data is accumulated.

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APPENDIX

Variable Definitions and Data Source

All series are quarterly data and seasonally adjusted as needed. They come from various sources and cover the period from 2000Q1 to 2020Q2. The specific variable definitions and sources are provided below.

Real Exchange Rate (*q*) Real exchange rate (*q*) is derived from the nominal exchange rate (*s*) in units of the RMB per unit of the US$, adjusted for the relative changes in consumer price indices (CPI), from Eq. (1) $q_t \equiv s_t - p_t + p_t^*$, all in natural logarithms. The nominal exchange rate and CPI were all obtained from the Bank for International Settlements.

Relative productivity (bs) Relative productivity is proxied by the relative price ratio of CPI/PPI: $bs = (cpi - ppi) - (cpi^* - ppi^*)$, where *cpi* and *ppi* denote CPI and PPI in logarithm terms. The justification is that PPI mainly concerns prices of the tradables, and CPI covers essentially non-tradable prices. The US PPI data are from FRED, and the China PPI from the National Bureau of Statistics of China, all seasonally adjusted.

Relative Terms of Trade (*tot*) Terms of trade is defined as the ratio of export to import prices. So relative terms of trade (*tot*) between China and the US is measured by: $tot = \ln(P_{EX}/P_{IM}) - \ln(P_{EX}^*/P_{IM}^*)$, where P_{EX} and P_{IM} are export and import price index, respectively. All commodity export (import) price indices are from the IMF Commodity Terms of Trade dataset. Two sets of indices are used, one is rolling weighted by individual commodities ratio to GDP, and another is weighted by their ratio to the total commodity exports (imports).

Net Foreign Assets (*nfa*) Net foreign assets (*nfa*) is defined as the net international investment positions (NIIP) as a percentage of real GDP. The quarterly NIIP data from China's State Administration of Foreign Exchange (SAFE) are only available from 2011Q1. To cover the year gap, we also used the SAFE's annual data from 2004 to 2010 and External Wealth of Nations data (Lane & Milesi-Ferretti, 2006) from 2000-2003 and then interpolated all annual data to quarterly using cubic splines.

Net Exports (*nx*) This is China's total exports minus total imports as a ratio to China's nominal GDP. The net export data are from the National Bureau of Statistics of China, which compiles data originally from China's General Administration of Customs.

Central Bank's Intervention (*fx*) The PBoC's intervention is measured by the official reserve position per GDP as: $fx_t = (OR/GDP)_t$, where the total official reserves (*OR*) exclude gold, SDRs, IMF positions, and other assets; both *OR* and *GDP* are in nominal terms. The total official reserves data is from the State Administration of Foreign Exchange (SAFE). We also applied the U.S. Treasury's methodology of estimating a central bank's intervention in the market by subtracting an estimated interest income on existing reserves from the reserve change.