Estimating Renminbi (RMB) Equilibrium Exchange Rate

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Abstract

It is claimed that China's currency market interventions have caused massive trade imbalances in favor of China. Without an accurate estimate of RMB's long-run equilibrium value, however, the validity of this claim can't be ascertained. This paper aims to place the debate about the degree of RMB's misalignment in a tractable framework by estimating the long run equilibrium real effective exchange rate of the currency with respect to the United States dollar. Based on estimation of the behavioral equilibrium exchange rate (BEER) and using Johansen co-integration technique, we conclude that RMB fluctuates around its long-run equilibrium rate within a narrow band. This implies that the currency has not been consistently undervalued. We identify the money supply, the foreign reserve holdings of China's central bank, Chinese terms of trade, and a measure of China's productivity as important explanatory variables of renminbi long-run equilibrium value. Based on the finding of RMB's minor misalignment from its real long-run equilibrium value, China exchange rate policy may have played an insignificant role in China's trade surplus.

Keywords: co-integration analysis; Renminbi equilibrium exchange rate; real effective exchange rate, U.S.-China Trade.

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1 Introduction

China's exchange rate policy has emerged as an issue of major contention between the P.R. of China and the United States of America, recently. The controversy is fuelled by China's pegging of RMB to USD. Since a major devaluation of the RMB in 1994, the currency's exchange rate vis-a-vis USD remained more or less unchanged until mid-July 2005, and has fluctuated within a very narrow margin of RMB8.11=USD1 since then.

In most of the period between 1994 to the time of this writing, the United States has experienced substantial trade imbalance with China. The combination of pegging of the RMB to the USD and the U.S. trade deficits with China has created a controversy on Sino-American trade relationship, with some influential centers in America arguing that China has deliberately undervalued its currency with respect to dollar by interventions in the currency markets[1] . Even though the exact size of undervaluation of the currency is not known, the estimates of undervaluation of the RMB vary from a little over zero to as high as 60% (see, for example, Coudert and Couharde, 2005).

In spite of uncertainties associated with the existence and size of RMB undervaluation, the critics of China's exchange rate policy claim that pegging of the RMB to USD has resulted in massive trade imbalances in favor of China (over $202 billion for 2005). China, on the other hand, responds that the current dollar price of the RMB is a reflection of productivity differential between the U.S and China, and that the current nominal RMB-dollar exchange rate has little, if any, impact on the current balance of trade between the two countries. Moreover, based on economic theory, it is claimed that any appreciations of the RMB would have at best only a temporary positive effect on America's trade balance with China [see Higgins and Humpage (2005)].

Clearly, the validity of the respective arguments hinges upon definition of the equilibrium RMB-USD exchange rate. Without knowing the estimated long-run, equilibrium RMB-USD rate, verification of whether RMB is over or under valued is rather problematic. To help placing the debate in a tractable setting, in this paper, we aim to estimate the long-run equilibrium RMB-USD exchange rate.

Specifically, we use the behavioral equilibrium exchange rate (BEER) approach, in estimating the renminbi equilibrium rate using annual data for the period 1980-2004. We

[1] See the Congressional testimonies by Goldstein (2003), Taylor (2003), and Bergsten (2006).

estimate BEER based on Johansen method, specify the error-correction model, and filter the data by the Hodrick-Prescott filter (H-P filter) to eliminate short-run and random effects on the estimated BEER data.

The paper is organized as follows. In section 2, we give a very brief account of China's exchange rate policy of the last twenty years. In section 3, we review, by now, the extensive literature of the studies dealing with estimating renminbi. Section 4 deals with the theory of equilibrium exchange rate. In section 5, we discuss variable selection for inclusion in the long-run equilibrium exchange rate model. Section 6 deals with time series econometrics of unit root test, cointegration, error correction model, and presents the empirical results. Finally, in section 7 we present a summary and some concluding remarks.

2 China's Recent Exchange Rate Policies

Before 1978, China's exchange rate policy was mostly determined by the nation's strategic interests, and was formed in the context of the tense, inhospitable climate of the Cold War that the new Republic's leaders faced. With the beginning of economic reforms in China, functions of the market were increasingly valued by the policy makers, and from 1981, a dual exchange rate system emerged, whereby, the official fixed exchange rate was complemented with market-determined exchange rate in the swap centers.

In 1988, the swap centers were established so that the transactions of the exporters, importers, and other currency dealing entities could be centralized. Prior to the establishment of the swap centers, these dealers exchanged currencies in fragmented exchange rate markets. In early 1990s, the swap market rate depreciated sharply, and the official rate became highly overvalued. In 1994, the official rate was devalued according to the swap market-determined rate, from 5.8RMB/USD to 8.7RMB/USD, and the exchange rate regime was officially defined as a managed floating system. The new rate remained more or less stable until July 21, 2005, when China revalued the RMB by 2.1 % to RMB8.11=USD1, and announced that it would switch from dollar-peg to a basket-peg.

3 Literature Review

Studies of estimating the RMB equilibrium exchange rate abounds; however, the results pertaining to misalignment of the currency is mixed at best. In what follows, we present the findings of some of these studies.

The RMB long-run equilibrium studies could be classified into two categories. First, a set of studies that are based on the purchasing power parity (PPP) theory. Second, another set of studies that aims to estimate the RBM equilibrium exchange rate using structural econometric models that are based on the economic fundamentals. These models go under a variety of names such as the behavioral equilibrium exchange rate (BEER), the fundamental equilibrium exchange rate, (FEER), the permanent equilibrium exchange rate, (PEER), and the equilibrium real exchange rate (ERER)[2] .

Studies that used the PPP method of estimation of the equilibrium RMB rate include Yu Qiao (2000), Dou XiangSheng and Yang Xi (2004). Both of these studies found that RMB is not undervalued. Funke and Rahn (2005), Coudert and Couharde (2005) used both PPP approach as well as economic fundamental approach in estimating misalignment of the RMB. Funke and Rahn found no significant undervaluation of the currency, while Coudert and Couharde (2005) found RMB's misalignment of 43 to 50% with respect to the USD[3]. Goh and Kim (2005) tested for misalignment of the RMB using economic fundamentals and co-integration method and could not find any evidence of undervaluation of the RMB, either.

4 The Equilibrium Exchange Rate

For the subsequent analysis, it is useful to have clear descriptions of various methods of the equilibrium exchange rate estimation.

We begin with a discussion of the fundamental equilibrium exchange rate (FEER). The FEER is both a definition for the real exchange rate and also a method of estimating it. Conceptually, the FEER refers to that long-run equilibrium exchange rate which is consistent with the external and internal macroeconomic equilibrium (Williamson, 1994)[4] . As a method of estimation, it specifies the equilibrium rate as a function of the fundamen-

[2]For detailed discussions of these and other equilibrium exchange rate estimation methods see Clark and MacDonald (1999).

[3]See Coudert and Couharde (2005) for the list of other studies which found that the RMB is undervalued.

[4]Williamson developed this concept to discourage analysts to focus on the notion that the equilibrium exchange rates depend on the equilibrium in the money markets, and instead encourage them to think of the disequilibrium rate, a rate that could not allow simultaneous external and internal macroeconomic balance. For details, see Williamson, 2003.

tal economic variables, abstracts from the short-term economic fluctuations, and entirely focuses on the medium-term and long-term economic conditions. Its weakness lies in difficulties of measurement, since such measurement involves a large number of parameters that relate to the current and capital accounts as well as the domestic capital and labor markets. Accordingly, the estimated results using this method become sensitive to the model's parameters.

The behavioral equilibrium exchange rate, the BEER approach, does not estimate the real equilibrium exchange rate per series, but it attempts to estimate the misalignment of a currency as the difference between the estimated exchange rate by the FEER method and the actual, observed exchange rate (see Clark and MacDonald, 1999).

4.1 Behavioral Equilibrium Exchange Rate of RMB

In this paper the BEER method uses a reduced form model of the fundamentals that determine the equilibrium exchange rate. The reduced form is specified as follows: the RMB real effective exchange rate (REER), terms of trade(tot), the relative price of the trade goods to non-trade goods (Balassa-Samuelson effect, named tnt), foreign exchange reserve (res), and the change of money supply (mon) as a measure of monetary policy. Here we can establish the RMB behavioral equilibrium exchange rate model as follows:

$$q^* = \alpha + \beta_1 res + \beta_2 mon + \beta_3 tot + \beta_4 tnt + \mu \tag{1}$$

where q^* represents *real equilibrium exchange rate*, and μ is the error term. Denoting the *actual (observed) real exchange rate* as q_t, we form the following relationship:

$$\Delta q_t = \theta(q_t^* - q_t) + \varepsilon \tag{2}$$

ε is regarded as random disturbance, and θ is the adjustment coefficient. As an example of a random, short-run variables that could affect real exchange rate, one can cite international speculation on RMB in 2005[5].

Combining (1) and (2), the equation becomes:

$$q_t = \theta\alpha + (1-\theta)q_{t-1} + \theta\beta_1 res + \theta\beta_2 mon + \theta\beta_3 tot + \theta\beta_4 tnt + \theta\mu \tag{3}$$

[5] In 2005, about 100 billion dollars "hot money" poured into China to speculate on revaluation of RMB, leading to a jump in real estate prices in some big cities of China. See China Economic Time(2005).

In a compact way, we specify model (2) as follows:

$$BEER = f(mon, res, tot, tnt) \tag{4}$$

5 Variable Selection

We select variables for inclusion in this study based on whether they impact the equilibrium exchange rate in the long-run or short-run. The long-term variables are those which influence the currency's value. These variables include terms of trade, the GDP growth rate, the technological advances, the price level, the interest rates, and the net capital flow. Since capital controls exist in China, the likelihood of high volatility of foreign exchange reserves in the short-run is very small. Therefore, we consider net capital flow as a long-term variable affecting the exchange rate.

The short-term variables force the real effective exchange rate to depart from the equilibrium exchange rate. However, their influence on the exchange rate is temporary, and they have no impact on the long-term trend of exchange rate. The typical short-term variables include instruments of the monetary and fiscal policies. We now elaborate on these short and long-term variables.

(i) Terms of trade: terms of trade is defined as the ratio of the export price index to the import price index. In this paper, this variable is expressed in log form: (tot)

(ii) Relative price of non-tradable to tradable goods: this variable can also be named as internal price ratio based on the Balassa-Samuelson model. This effect is based on the divergence of productivity levels in a country's non-tradable and tradable goods. The rise in total factor productivity in the tradable sector combined with inter-sectoral labor mobility raises wages in both sectors. However, even though prices in the tradable sector remain more or less stationary (because both wages and labor productivity in this sector have risen proportionately), the increasing wages in the non-tradable sector, without a compensating higher productivity in the sector, increases non-tradable prices. As a result, the internal price ratio will increase also. If the internal price ratio of a country falls, the real effective exchange rate of the country is undervalued; on the other hand, if the internal price ratio of a country increases, the real effective exchange rate become overvalued.

Usually, the non-tradable prices are expressed by consumer goods price, and tradable goods price is expressed by the wholesale price in empirical test, so internal price ratio is defined as the ratio of the domestic consumer price index to the domestic wholesale or producer price index (Peter B.Clark and Ronald MacDoonald, 1998). However, the use of these proxies is problematic for there are many tradable items in the composite of the goods that form the basis for consumer price index number construction. Moreover, in China, because of widespread price controls and restrictions on free movement of workers between different sectors of the economy, the Balassa-Samuelson effect may not apply. Therefore in this study we use per capita output as a rough measure of change in the productivity in China. This variable is also expressed in log form:(tnt).

(iii) The interest rate differential: Because of capital controls, we do not use the interest rate differential between China and the rest of the world in this study.

(iv) Foreign exchange reserve: This variable refers to the total stock of net foreign assets accumulated by the central bank of China, Bank of China. An increase in the foreign exchange reserve holdings implies the demand for the home currency is high, resulting in the real exchange rate appreciation. We denote this variable as (res).

(v) Money supply: An increase in the money supply would cause the real exchange rate to depreciate, and a reduced money supply would force the exchange rate to appreciate. In this paper, this variable is expressed as (mon). Note that we use the differenced, log of all variables in model estimation.

6 Empirical Results

In this study we use Johansen's ML (Maximum Likelihood) cointegration technique to estimate model (4). Before cointegration analysis, it is necessary to test for presence of unit roots in the time series to avoid spurious regression. We use the Augmented Dickey-Fuller (ADF) test to determine whether the variables of model (4) are stationary in first difference.

6.1 Unit Root Test

There are three situations in ADF test for every time series. First, random process includes intercept (c) and trend (t). Second, random process includes intercept but no trend. Third, random process includes no intercept and trend. Which one do we choose in this paper? One empirical approach suggests visual observation of the time series plot of the data (Zhang Xiao Tong 2003). If the graph shows such characteristics as changing variable over time (increase or decrease) and no obvious steep trend, then the time series is best represented by the second situation. After observing the graphs of all variables in the model, we employ a model with intercept and without trend. On the other hand, because of using annual data and small samples, lags ($n = 1$) is adapted. Therefore, we choose $(c, t, n) = (c, 0, 1)$ in ADF test. The results of the test show that the variables of the real effective exchange rate, money supply, the foreign exchange reserve, the terms of trade, the internal price ratio are respectively stationary in first difference. In other words, these variables are $I(1)$ or integrated processes at the level. The results are presented in Table 1. Accordingly, the test rejects the null hypothesis that there is a unit root in first difference of every variable at 5% significant level (for variables of *reer* and *tnt*) and at 1% significant level (for variables of *res*,*mon*,*tot*).

Table.1. ADF Test Results For the Variables for REER Model

variables	Type of Test(c,t,n)	ADF test statistic	1% criti- -cal value	5% criti- -cal value	D.W statistic
reer	c 0 1	-2.022921	-3.689194	-2.971853	1.186360
d(reer)	c 0 1	-3.563409	-3.699872	-2.976263	1.511758
res	c 0 1	-0.420301	-3.689194	-2.971853	1.786394
d(res)	c 0 1	-4.085388	-3.699871	-2.976263	1.591328
tnt	c 0 1	-1.817892	-3.689194	-2.971853	1.143206
d(tnt)	c 0 1	-3.377546	-3.699871	-2.976263	2.053528
mon	c 0 1	-0.509533	-3.689194	-2.971853	1.909527
d(mon)	c 0 1	-5.273594	-3.699871	-2.962630	2.544137
tot	c 0 1	-1.845153	-3.689194	-2.971853	1.395297
d(tot)	c 0 1	-6.755172	-3.699871	-2.976263	1.625046

Note: Terms c,t, and n represent intercept, trend, and lags, respectively. d represents first difference.

6.2 Johansen Cointegration Method

Given that all series in the model are $I(1)$ processes, we next test whether they have cointegration relationship. First, considering sensitivity of VAR model to the number of lags of the variables, the optimal lags of the variables of the model must be determined. In this work, we use FPE (Final Prediction Error), AIC (Akaike Information Criterion), SC (Schwarz Information), HQ(Hannan-Quinn Criterion). According to the results of these tests, we choose lag 3 in the VAR model. The results of test on the optimal lag selection are shown in (Table 2):

Table.2. Statistics for Selection of Number of Lags

Lag period (p)	FPE	AIC	SC	HQ
0	6.38E-07	-0.076	0.1725	-0.01701
1	5.51E-11	-9.50418	-8.016393	-9.153701
2	1.02E-11	-11.60856	-8.880953	-10.96602
3	2.23E-13	-16.89776	12.93033	-15.96315

Table 3 presents the trace and maximum eigenvalue statistics for the VAR model. The first column shows H_0 , with $r = 0$, $r \leq 1$, $r \leq 2$, $r \leq 3$ denoting no, at most 1, at most 2, and at most 3 cointegrating relationships. The second column represents Eigenvalue, the third column represents the trace and Max-Eigen statistics. The remaining columns present the 5% and 1% critical values. These statistics indicate that only one null hypothesis is rejected. This implies that there is only one cointegrating equation ($r = 1$) among the five variables at 1% significant level (Table.4).

Table 3. VAR Cointegartion Test Statistics

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5% Critical Value	1% Critical Value
r=0 **	0.994931	205.7886	68.52	76.07
$r \leq 1$*	0.904790	89.52758	47.21	54.46
$r \leq 2$	0.563035	37.79078	29.68	39.65
$r \leq 3$	0.389773	19.57694	15.41	20.04
Hypothesized No. of CE(s)	**Eigenvalue**	**Maximum-Eigen Statistic**	**5% Critical Value**	**1% Critical Value**
r=0 **	0.994931	116.2610	33.46	38.77
$r \leq 1$ **	0.904790	51.73680	27.07	32.24
$r \leq 2$	0.563035	18.21384	20.97	25.52
$r \leq 3$	0.389773	10.86634	14.07	18.63

Note: $*(**)$ denotes rejection of the hypothesis at the 5% and (1%)significance levels.

Table 4. Estimation of Cointegrating and Adjustment Coefficients

Normalized cointegrating coefficients					
reer	res	tnt	mon	tot	C
1.00000	-o.859256	-1.254370	1.178786	-0.337051	-5.508505
	(0.00076)	(0.00272)	(0.00211)	(0.00435)	
	[-5.11308]	[2.84330]	[2.33567]	[1.18025]	
Adjustment coefficients					
D(reer)	D(res)	D(tnt)	D(mon)	D(tot)	
-0.105554	2.735621	-0.142560	0.442322	-0.263274	
(0.07648)	(0.37525)	(0.05954)	(0.15449)	(0.06209)	
[-1.25288]	[5.38878]	[-4.02993]	[2.52119]	[-1.96410]	

Note: Standard errors of estimate appear in the parentheses, and t-statistics are in the brackets.

From Table 4 we obtain the following cointegartion equation:

$$REER = 0.859256res + 1.254370tnt - 1.178786mon + 0.337051tot + 5.508505 \qquad (5)$$

Since REER is the reduced form of BEER, we refer to (5) as REER (real equilibrium exchange rate) here. It is can be seen from the equation that all coefficients conform to the economic theory. This equation indicates that the money supply, the foreign exchange reserve, per capital GDP, and the term of trade in China have long-term stable equilibrium relationship. For example, a 1% rise in the money supply causes a 1.179% depreciation in the currency. Moreover, the results also indicate that a 1% increase in per capita GDP causes a 1.25% RMB appreciation. Furthermore, for each 1% increase in foreign reserves, RMB will revalue 0.86%. However, the improvement of terms of trade has no obvious effects on RMB.

Finally, it should be pointed out that the improvement of term of trade of a country should commonly cause currency revaluation; however, two effects of the terms of trade, that is, the income and substitution effects, should be considered here. First, let us discuss the income effect. The increasing export prices cause the real income to rise, increasing the demand for non-tradable goods that could lead to real exchange revaluation. Second, the substitution effect arises when a drop in the import price causes an increase in the import demand thus lowering the demand for non-tradable goods. This effect often leads to the real exchange rate devaluation. Accordingly, the effect of the terms on the equilibrium real effective exchange rate is indefinite. In the estimated equation, the coefficient of tot is positive, which means change of term of trade brings more income effect than substitute effect, implying that a rise in term of trade could cause currency appreciation.

6.3 Vector Error-Correction Model and Diagnostics

Because RMB exchange rate has the co-integration relationship with economic fundamentals, there exists a vector error-correction (VEC) model describing the adjustment mechanism of the exchange rate from short-term to long term. We can specify the vector error-correction model as follows:

Considering rank k VAR model:

$$Y_t = \Pi_1 Y_{t-1} + \Pi_2 Y_{t-2} + \cdots\cdots + \Pi_k Y_{t-k} + \mu_t \tag{6}$$

Where Y_i is an n-dimensional vector.[6] Supposed $Y_i \sim I(0)$.

[6] For details see Campbell, J. A. Lo and C. MacKinlay (1997) and Watson, M. (1994).

Then from (6) get:

$$\Delta Y_t = \Gamma_1 \Delta Y_{t-1} + \Gamma_2 \Delta Y_{t-2} + \cdots\cdots \Gamma_{k-1} \Delta Y_{t-k+1} + \Pi Y_{t-1} + \varepsilon_t \tag{7}$$

and

$$\Pi = \sum_{i-1}^{k} \Pi_i - l,\ \Gamma_i = -\sum_{j=i+1}^{k} \Pi_j\ (i = 1, 2, \cdots, k-1) \tag{8}$$

So $\Pi = \alpha\beta'$. β as a parameter matrix,is sometimes called the long-run parameters, where each row in the matrix represents an integrating vector. $\beta = (\beta_1, \beta_2, \cdots, \beta_r)$ has r cointegrating vector, β'.

$Y_{i-1} \sim I(0)$, contains r error correction term (ECT). α is called adjustment coefficient matrix. Each element in α represents the speed of adjustment of the error correction term.

So equation (7) can be written as follows:

$$\Delta Y_t = \Gamma_1 \Delta Y_{t-1} + \Gamma_2 \Delta Y_{t-2} + \cdots\cdots \Gamma_{k-1} \Delta Y_{t-k+1} + \alpha\beta' Y_{t-1} + \varepsilon_t \tag{9}$$

Equation(8) is called vector error correction model (VEC). It is a restricted VAR designed for use with nonstationary series that are known to be cointegrated. The VEC has cointegration relations built into the specification so that it restricts the long-run behavior of the endogenous variables to converge to their cointegrating relationships while allowing for short-run adjustment dynamics. The cointegration term is known as the error correction term since the deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments.

Herein, based upon the analysis above, we can obtain the following equation from(5):

$$vecm = reer - 0.859256res - 1.254370tnt + 1.178786mon - 0.337051tot - 5.508505 \tag{10}$$

Variable vecm can be regarded as the core of VEC model. Adjustment coefficient $(-0.105554 < 0)$ (Table 4) is negative, which means if the real exchange revalues, it will be adjusted downward, vice versa. The dynamics of the error correction model would force it back toward the long-run equilibrium.The bigger of absolute value of adjustment coefficient, the faster is the adjustment speed. If the adjustment coefficient reaches absolute value 1, it means that misalignment will be adjusted in 1 year. In this paper, RMB real effective exchange rate undervalues, it needs revalue at the rate of 10.5% in one year, and RMB would appreciate gradually. In the short term, the real effective exchange rate is also influenced by the fundamental economic factors; money supply and the foreign exchange reserve also have distinct influence on the fluctuation of the exchange rate. It appears that both short term and long-term variables have a unidirectional effect on the equilibrium exchange rate. Therefore, the rise in the GDP, the increase in foreign exchange reserve, and the decrease in the money supply would lead to the appreciation of the real effective exchange rate.

The residuals in the VAR (VEC) model, need diagnostic tests (see the appendix 1 for discussions of these diagnostic tests), by which we may further examine whether all variables retain their long-run cointegrating relationships. The results in Table 5 indicate that variable satisfy the test conditions.

Now, we focus on estimating the value of the cointegration equation (5). Taking the actual values of fundamentals variables (res, tnt, mon tot) in (5), we can estimate the current actual equilibrium exchange rate of RMB (BEER). To abstract from the short, random disturbances in BEER, we use the H-P filter technique (see the appendix 2), then we obtain the stable and permanent BEER value, that is labeled as HPBEER in figure 1. Compared with actual REER, at last, we can barely observe misalignments in RMB effective exchange rate (figure 2).

Table.5. (VAR\VEC) Model Evaluation and Diagnostics

VEC stability condition check:	(1) VEC specification imposes 4 unit root(s). (2) all roots have modulus less than one and lie inside the unit circle The estimated VAR/VEC is stable
Autocorrection LM test	LM1 LM2 87.39 95.59 (0.0000) (0.0000) No Autocorrection
Heteroskedasticity test	$x^2(330) = 356.67$ (0.1499) No Heteroskedasticity
Jarque-Bera normal rest	$x^2(10) = 19.78$ (0.0314) in agreement with normal distribution.

Figure 1: REER and HPBEER of Remninbi-Dollar Exchange Rate

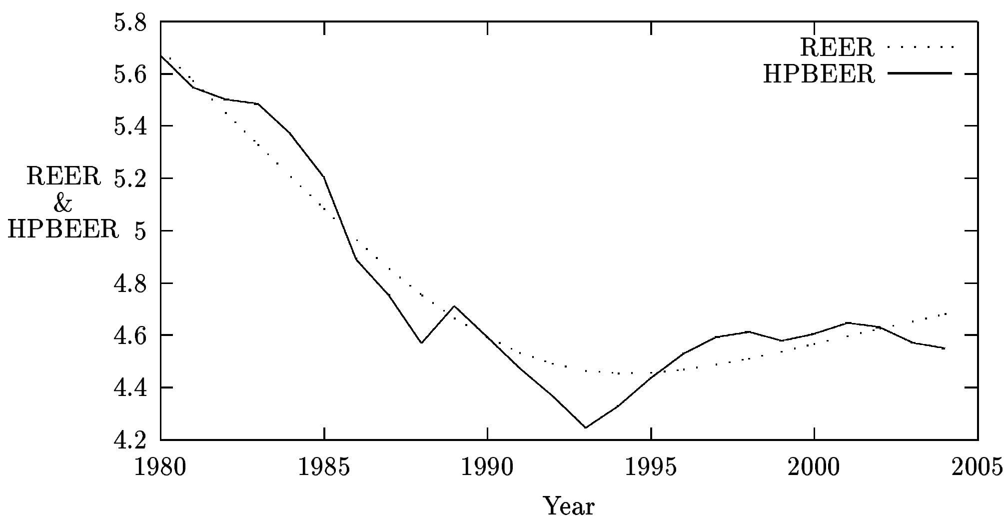
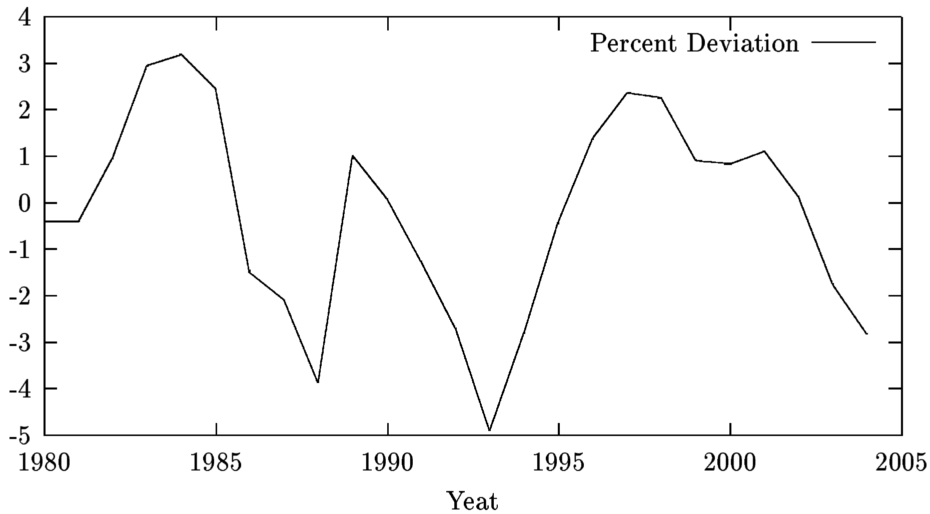


Figure 1 shows the relationship between the REER and the filtered BEER for China during 1980-2004. As it can be seen form the graph, the two series move in close proximity of each other, and the degree of divergence between the series is rather small. Maximum degree of under valuation of RMB is about 5% (approximately in 1993), and maximum of degree of over valuation of RMB is about 3% (in 1984)(Figure 2).

During 1982 and 1986, the real effective exchange rate is higher than the equilibrium ex-

Figure 2: Precent Misalignment of RMB-USD



change rate estimated by the BEER model. From 1990 to 1995, RMB real effective exchange rate is lower than the equilibrium exchange rate estimated by the BEER model. Since 1995, the real effective exchange rate is nominally higher than the equilibrium rate. Around 2002, equilibrium exchange rate is higher than real effective exchange rate. Especially since 1999, the degree of misalignment between real effective exchange rate and equilibrium exchange rate is diminishing. During 2002 to 2003, the RMB shows appreciation. Since then, the RMB exchange rate appears to appreciate slightly. However, according to the Figure 1, pressure for appreciation persists.

7 Conclusions

The empirical results in this study indicate that there has been little, if any, misalignment in renminbi during the last 25 years. The estimated coefficients of the VAR model testing for cointegration relationship are in conformity with economic theory. Specifically, coefficient of the money supply shows an inverse relationship between the money supply and the exchange rate movement. While the coefficient of the China's foreign currency reserve, terms of trade, and productivity measure all point to positive relationship between the explanatory variables and the real equilibrium exchange rate.

Looking at the issue prospectively, we notice that two variables may have profound impact on the future value of RMB. From the estimated model, it can readily been seen that increase of the foreign exchange reserve and increases in foreign direct investment in China could act as the major forces for the revaluation of RMB in near future. However, potential capitals outflow may have negative impact on revaluation of RMB. Nevertheless, capital flows and foreign reserve accumulations are two major policy instruments that are available to policy makers. Accordingly, the debate on China's exchange rate policy needs to focus on these two variables for brining about meaningful, long-lasting, and mutually-beneficial changes in China's exchange rate policies.

Appendix 1

The Hodrick-Prescott (HP) filter estimates an unobserved time trend for time series variables. The procedure was first introduced by Hodrick and Prescott in the context of business cycle estimation in 1980.

Let Y_i denote an observable (macroeconomic) time series. The HP filter decomposes Y_i into a nonstationary time trend (P_i) and a stationary residual component (R_i), that is:

$$Y_i = P_i + R_i$$

Note that both P_i and $R_i$ct are unobservables. Since R_i is a stationary process we can think of Y_i as a noisy signal for the nonstationary time trend P_i, Hence, the problem is how to extract an estimate for P_i from Y_i.The HP filter solves this problem by allocating some weight for the signal against a linear time trend. Let λ represent that weight. For $\lambda = 0$ we assume that there is no noise, i.e. $Y_i = P_i$, and as λ gets larger more and more weight is allocated for the linear trend. That is, as $\lambda \to \infty$, P_i approaches the ordinary least squares estimate of Y_i's linear time trend. Hodrick and Prescott show that under some conditions the best choice of λ is driven by the relative variances of R_i and the second difference of P_i.

Appendix 2

VEC diagnostic method: it mainly contains:

i. stability condition check

The estimated VAR is stable (stationary) if all roots have modulus less than one and lie inside the unit circle. see Lütkepohl (1991).

ii. Autocorrelation LM Test

The test statistic for lag order is computed by running an auxiliary regression of the residuals on the original right-hand regressors and the lagged residual , where the missing first values of are filled with zeros. See Johansen (1995) for the formula of the LM statistic. Under the null hypothesis of no serial correlation of order the LM statistic is asymptotically distributed with degrees of freedom.

iii. Normality Test

The test compares the third and fourth moments of the residuals to those from the normal distribution. Since each component is independent of each other, we can form a statistic by summing squares of any of these third and fourth moments.

iv. White Heteroskedasticity Test

Each cross product of the residuals is regressed on the cross products of the regressors and testing the joint significance.

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