Behavior equilibrium exchange rate and misalignment of Renminbi: A recent empirical study

Jinzhao CHEN *

Abstract

This paper employs the behavioral equilibrium exchange rate (BEER) model to estimate the equilibrium real exchange rate of Renminbi (RMB) and the exchange rate misalignment in China, which covers the period from 1994q1 to 2006q2. Using the most precise and recent data, the main findings of the paper are that (1) since 1994q1, RMB equilibrium exchange rate has exhibited a steady appreciation, but from the 1999q3 to the recent period, it started to depreciate. And (2) that RMB real exchange rate has been under-valuated during the most part of sample period, but this misalignment has a trend to become smaller and small, and in recent after-reform period, a small degree of over-evaluation replaces this under-valuation.

JEL classification: F31, F32, F41, C32

Keywords: Behavior equilibrium exchange rate, cointegration, misalignment, Renminbi

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I. Introduction

The hot debate about the appropriate level of exchange rate of Renminbi\(^1\) (RMB) and the recommendations for appreciating it or adapting a floating exchange rate regime or both were principally based on the two facts below (Bénassy-Quéré et al, 2004; Coudert and Couharde, 2005): the growing size of the Chinese current account surplus from the end of 90s and the proliferation of its foreign exchange rate reserves (from graph 1 to Graph 3).

On one side, we can see (cf. Graph 2) that from 1998, after the Asian financial crisis, Chinese monetary authorities began to raise their foreign exchange reserves, and from 2000 this growth represents an exponential trend. On the other side, the current account started to soar from 2001 (cf. Graph 3). Being founded on these facts, have emerged a lot of discussions about these topics in business, academic and even political areas in form of conferences, academic papers and official statements\(^2\). Even though there are continual current account surpluses and capital inflows, the Chinese monetary authorities still kept *de facto* or *de jure* the fixed pegs on US Dollar, at this level the RMB was considered more or less under evaluated. This under evaluation is considered as the principal tool to sustain the competitiveness of Chinese exportations, which are considered as the reason causing the growing size of the US current account deficit. This even caused political pressure later from US government, for instance, a bill introduced into the U.S. Congress in March 2005 to impose a 27.5 percent tariffs on all Chinese imports, which is the prelude of the reevaluation and pegs on a basket of currencies of RMB on July 21st, 2005. But if we compare the current accounts of China and US (cf. Graph 3), we can conclude that the surplus of the current account of China can not compensate the whole deficit of current account of US. So we cannot make the definite decision that the RMB is under evaluated, and even though it is the fact, it is this under evaluation which causes this growing deficit of US current account. It is in this context that appeared a series of papers contributing to estimate the equilibrium exchange rate of RMB\(^3\), which is thought to be a good benchmark to evaluate the deviation of currencies from their right level and to clarify the derived monetary policy implications.

As to the methods used for estimating the equilibrium exchange rate, the Purchasing Power Parity (PPP) is always the first reference for estimating an equilibrium exchange rate thanks to its simplicity (Rogoff, 1996). This approach assumes a base period at which the real exchange rate is believed to be in its equilibrium level. The deviation of the actual rate from that in equilibrium is calculated as misalignment (Williamson, 1985). Chou and Shih (1998) have used the PPP model to estimate the equilibrium exchange rates of the Chinese currency, the RMB. But this theory has some disadvantages: at first, the choice of base period depends on the subjective judgement about the economic variables in this period\(^4\); secondly, its vision of equilibrium is static, but in reality, as the economic fundamentals move too, the level of equilibrium may also change. In order to surpass these disadvantages, two other approaches are implemented to estimate the real equilibrium exchange rate. The one is fundamental equilibrium exchange rate (FEER) approach, proposed by Williamson (1985) and applied by a lot

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1 It is the name of the Chinese currency, sometimes used as “Yuan” which is the unit of account. In the rest of this paper, we use its abbreviation “RMB”.
2 Boca Raton (Florida) statements of G7 finance ministers in February 6-7, 2004.
3 In fact, the focus on the right level of exchange rate of RMB can back to the moment of East Asian financial crisis, when the exchange rate of RMB was widely thought overvalued. So the first time economists began to estimate its equilibrium exchange rate, see Yi and Fan (1997), Chou and Shih (1998).
4 It means that if they are in equilibrium.
of authors to both developed and developing countries (Williamson, 1985; Wren-Lewis and Driver, 1998). This approach involves calculating the real exchange rate which is consistent with macroeconomic balance, which is identified as the rate that equates the current account at full employment with sustainable net capital flows. The notion of equilibrium is that of macroeconomic balance and this is different from that incorporated in the other approach: the Behavior Equilibrium Exchange Rate (BEER) approach (Clark and Macdonald, 1998), which is involved with the direct econometric analysis of the behavior of the real effective exchange rate, the movement of the BEER reflex the movements of the associated economic variables. The equilibrium rate is the value adjusted by an appropriate set of such explanatory variables.

The most important difference between these two approaches, in point of view of application, is the feasibility: As to the FEER, under some assumptions lots of parameters in the equations are specified with normality. The results of estimations are very sensitive to the modification of parameters when certain hypothesis changes, especially for developing countries. By contrast, this kind of parameterisation is absent in BEER, and estimating a reduced-form equation is more practical. So it is largely applied to the estimation of real equilibrium exchange rate and misalignments (cf. Baffes et al., 1999; Clostermann and Schnatz, 2000; Maeso–Fernandez et al., 2002). Moreover, some variable specified in the FEER maybe do not, in reality, have an influence on the real exchange rate, or can not be verified because of inexistence of the data in some countries; with BEER, even though there exists some problems when study the misalignment of exchange rate for the developing countries, for instance, small sample or bad quality of data, the instability of economic structure etc, BEER is proved to be efficient and powerful for finding the long-run relation between the real exchange rate and its fundamental variables (Montiel, 1999a). Basing on these mentioned facts, we prefer the BEER approach to the FEER for estimating the behavior equilibrium exchange rate of Chinese currency.

This paper aims to assess empirically the equilibrium real exchange rate and the associated misalignment of the RMB using the time series data of China, from the first quarter of 1994 to second quarter of 2006. In the literature, there are some empirical papers about this kind of estimation, some of them using the BEER approach (Zhang, 2001; Zhang, 2002; Bénassy-Quéré et al, 2004; Shi and Yu, 2005 etc). This paper differs from the earlier research in several respects. First of all, instead of calculating the bilateral real exchange rate which is used by some authors (Zhang, 2001; Coudert and Couharde, 2005), the multilaterals CPI-based real effective exchange rate (REER) is calculated in this paper, weighted by the trade ratio of China’s 13 biggest partners. It means a more precise calculation of real exchange rate, even though some authors have already used the multilateral REER (Funke and Rahn, 2004, Zhang, 2002). Secondly, we use a new database which includes the recent quarterly data. Lin (2001) and Zhang (2001) used annual data, but in order to increase the size of the sample, they include the data before 1990, even back to 1950. In these circumstances, the sample includes several different exchange rate regimes, and before 1980, the prices were controlled by Chinese government as a tool for planned economy. So the credibility of their estimation is not sure. For these reasons we choose using quarterly data to guarantee a big size of the sample, just as some paper did (Zhang, 2002; Funke and Rahn, 2004; Shi and Yu, 2005). But their estimations are limited to the period which is before the exchange rate regime reform of 2005, so our paper completes this shortage by offering the estimation from the first quarter of 1994 to recent period. Finally, in

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5 We will discuss this approach in detail in the next section.
6 Funke and Rahn choose United States, Japan and euroland as china’s trade partners; Shi and Yu choose 7 partners countries (or religions).
7 From this time, a unified exchange rate regime has been established in China.
order to compare our estimations with the recent research, we choose the same independent variables as that chosen by Shi and Yu (2005) and use our new data to assess the equilibrium rate and misalignment of RMB. We find that RMB is almost under-valuated during the majority of the sample period. But the degree of misalignment is very small and the biggest undervaluation is just high to 3.94%. This small size of misalignment is consistent with the result of the paper using the Chinese data. And we find that this under-valuation have a tendency to decrease, especially for the after-reform period from the third quarter of 2005.

The rest of this paper is organized as follows: in the second section, the empirical approach—the BEER approach and Econometrics Methods, especially the cointegrating methods, are presented. The definitions of the variables and the data sources are presented in the third part. Then we give the results of estimation, analyze them and give our interpretations. In the final section, we conclude with future direction of research.

Graph. 1
The Foreign Reserve of China (Stock in billion US dollars)

Source: SAFE, China

Graph. 2
The Foreign Reserve of China (Flows in billion US dollars)

Source: OECD Stat

Graph. 3
The Current Account of China (In million US dollars)

Source: OECD Stat
II. Theoretical Framework: the determinants of real exchange rate

Before implementing the BEER approach, we should choose the economic fundamental variables as the determinants of real exchange rate. In this paper there are four economic fundamentals which are chosen: the relative price of non-traded to traded goods (the Balassa-Samulalson effect), net foreign assets position, term of trade and commercial policy (degree of openness as the proxy). As to this choice of these fundamental variables, there are three principle reasons: first of all, as mentioned above, one objective in this paper is to compare our result obtained with the new data with that of Shi and Yu (2005), naturally, we choose the same fundamental variables as that they choose. Secondly, BEER itself is not a theory of determination of real exchange rate, it needs the guidance of other theories when choosing the determinants. Our manner to do this conforms to this point. All of these variables are identified in some theoretical models, for example, Faruqee (1994), MacDonald (1997) and Montiel (1999), and are considered as the economic fundamentals to affect the real exchange rate: thirdly, as mentioned by Shi and Yu, we choose these variables according to the availability of data.

We will briefly explain these determinants of real exchange rate, as for a more precise definition of their proxies, see the next section. The first is the Balassa-Samulalson effect which is the source of systematic changes in the relative price of traded to non-traded goods, which is considered as a domestic supply side factor (Montiel, 1999). According to this effect, exchange rate appreciates if relative productivity in the tradable sector increases because it creates excess demand in the non-tradable sector. So it has a positive effect on real exchange rate.

The second one is net foreign asset position. Continuous current account deficit will reduce the net foreign asset position or even raise the net foreign credit, this require the future trade surplus to compensate it. The depreciation of real exchange rate is favorable to generate this surplus. So the deterioration of net foreign asset position will cause the depreciation of real exchange rate in the medium or long term. Oppositely, the increase of net foreign asset will cause the appreciation of real exchange rate. So this variable has a positive effect on real exchange rate.

The third one is the terms of trade which is related to international economic environment factor. Improvement in terms of trade increases national income in terms of imported goods which in turn may increase demand for tradable goods requiring an appreciation of currency. It means that the terms of trade can have a positive influence on real exchange rate.
Finally, commercial policy could have important effect on equilibrium real exchange rate. Trade liberalization or the rise of degree of openness reduces support to import competing industries and resources are channeled to non-traded goods sector, which ultimately results in depreciation. It means that the real exchange rate is affected by degree of openness negatively.

III. Empirical approach and Econometric Methods

A. The BEER Approach

We use the BEER approach to estimate the equilibrium exchange rate of RMB, because this method is well suited to developing countries in which large and complex models are often not feasible because of data limitations (Zhang, 2001). The discussion here about this approach is based on Clark and Macdonald (1998). An estimated reduced-form equation is used to explain the behavior of the real effective exchange rate with the associated economic fundamentals:

\[ q_t = \beta' Z_t + \tau' T_t + \epsilon_t \]  \hspace{1cm} (1)

\( Z \) = a vector of economic fundamentals that are expected to have influence on the real exchange rate over the medium and long run.

\( T \) = a vector of transitory factors affecting the real exchange rate in the short run.

\( \beta, \tau \) = vectors of reduced-form coefficients.

\( \epsilon \) = random disturbance term.

\( q \) = actual, observed real effective exchange rate.

The equation (1) means that the actual real exchange rate can be explained exhaustively by a set of fundamental variables, \( Z \), and some transitory variables that affect real exchange rate on the short run, \( T \), and the disturbance term, \( \epsilon \).

The current equilibrium rate is defined as the exchange rate determined by the current value of the economic fundamentals:

\[ q_t' = \beta' Z_t \]  \hspace{1cm} (2)

So \( \text{mis}_{\text{cur}} \) is defined as the difference between the actual rate and the real exchange rate determined by the current value of the economic fundamentals:

\[ \text{mis}_{\text{cur}} = q_t - q_t' = \tau' T_t + \epsilon_t \]  \hspace{1cm} (3)

But as mentioned above, it is possible that the current value of the fundamentals depart from their long run sustainable level, so the total misalignment, \( \text{mis}_{\text{permis}} \), is defined as the difference between the actual real rate
and the real rate determined by the long-run values of the economic fundamentals, which are denoted by $\overline{Z}_t$:

$$\text{mis \_ per}_t = q_t - \beta'\overline{Z}_t \quad (4)$$

With equation (2), we can decompose the total misalignment into two parts:

$$\text{mis \_ per}_t = (q_t - q_t') + \beta'(Z_t - \overline{Z}_t) \quad (5)$$

Form this equation it is clear that the total misalignment is composed of the current misalignment and the effect of departures of the current fundamentals from their long-run or sustainable values. Because of equation (3), the equation (5) can be written as:

$$\text{mis \_ per}_t = \tau T_t + \varepsilon + \beta'(Z_t - \overline{Z}_t) \quad (6)$$

Thus the total exchange rate misalignment at any time can be decomposed into the effect of transitory factors, random disturbances, and the extent to which the economic fundamentals depart from their sustainable values. In this paper, we choose 4 economic fundamentals as the variables in the vector $\overline{Z}_t$, in other words, the current equilibrium exchange rate is a function of these variables:

$$\hat{q}_t = f(tnt, NFA, tot, OPEN) \quad (7)$$

Where $tnt$ is the relative price of nontraded to traded goods, $NFA$ is net foreign assets, $tot$ is the terms of trade, $OPEN$ is the degree of openness. What we need to do is to estimate a single equation in the form below:

$$BEER = (tnt, NFA, tot, OPEN) \quad (8)$$

If we can identify a long-run relationship, here cointegration relationship technically speaking, between real exchange rate and its economic fundamentals, it means that the linear combination of these variables is stationary and the real exchange rate is mean reverting. As mentioned by Zhang(2001), the mean of this cointegating relationship can be identified econometrically as the equilibrium exchange rate towards which the actual real exchange rate gravitates over time. So we should test if there exists this cointegration relationship and derive the equilibrium exchange rate determined by it if it exists.

**B. Econometric Models and estimation method**

The econometric methods used here are Cointegrating method of Johansen (1995). The advantage of Johansen’s method is that it provides more robust results than other cointegrating methods when more than two variables are used, because it can not only provides a test for cointegration, but also tells the number of cointegrating relationships.

We will present briefly this approach. At first Consider an unrestricted vector autoregression (VAR), which includes "$p" lags:

$$x_t = \eta + \sum_{i=1}^{p} \prod x_i + \varepsilon_i \quad (9)$$
Where $x_t$ is a (nx1) vector of variables consisting of the variables included in (7) and (8) which may I(1) or I(0), $\eta_t$ is a (nx1) vector of deterministic variables, and $\varepsilon_t$ is a (nx1) vector of white noise disturbance term, with zero mean and covariance matrix $\Sigma$. Rewriting the above model, the following error correction form can be obtained:

$$\Delta x_t = \eta + \sum_{i=1}^{p-1} \Phi_i \Delta x_{t-i} - \Pi x_{t-1} + \varepsilon_t \quad (10)$$

$\Delta$ means the first difference operator, $\Phi_i$ is a (nxn) coefficient matrix (equal to $-\sum_{j=1}^{p} \Pi_j$), $\Pi$ is a (nxn) matrix (equal to $-\sum_{i=1}^{p} \Pi - I$) whose rank determines the number of cointegrating vectors. If is of either full rank or zero rank, $\Pi = 0$, there will be no cointegrating relationship among the elements in the long-run. Assume there are r cointegrating vectors among these variables, where $0 < r < n$. In this case, there will exist (nxr) matrices $\alpha$ and $\beta$ such that $\Pi = \alpha \beta'$. The matrix $\beta$ contains the parameters of the cointegrating vectors and the matrix $\alpha$ contains the weights with which the vectors enter the equations in the system, interpreted as the adjustment matrix, indicating that the speed with which the system responds to last period’s deviation from the equilibrium level of the exchange rate. Therefore, if the hypothesis concerning cointegration holds, the matrix $\beta'Z_t$ constitutes a set of r error-correction mechanisms separating out the long-run and short-run responses in the model, its existence determine the existence of the VECM model or a VAR in first differences.

Johansen (1988) and Johansen and Juselius (1990) present two likelihood ratio tests of null hypothesis that there are at most r cointegrating relationships among these variables. One test is based on the trace of the stochastic matrix $\Pi$ and tests the null hypothesis against the alternative that there are at least r+1 cointegrating vectors. The other is based on the maximal eigenvalue of the stochastic matrix n to test the null hypothesis that the number of cointegrating vectors is less than or equal to r against the alternative of r+1 cointegrating vectors.

IV. The Data sources and Definitions

The data are quarterly ones and their spans are from the first quarter of 1994 to second quarter of 2006. We will give the definitions of the variables and the data sources below (The data in logarithm form are expressed in lower case):

A. Real Effective Exchange Rate (REER):

The real effective exchange rate (REER) of RMB is a CPI-based trade-weighted real effective rate, 2000 being the base year$^8$:

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$^8$ IMF calculates and publishes in the IFS the CPI-based trade-weighted REER with the trade weights reflecting the relative
\[
REER = \prod_{i=1}^{N=13} \left[ \frac{S_{\text{China}} \cdot CPI_{\text{China}}}{s^i \cdot CPI^i} \right]^W^i
\]

\[
reer = \ln REER = \sum_{i=1}^{N=13} W^i \left( s_{\text{China}} + cpi_{\text{China}} - s^i - cpi^i \right)
\]

\( S_{\text{China}} \) (\( S^i \)) is the bilateral exchange rate of RMB (country i’s currency) in US dollars. The rise of \( S_{\text{China}} \) (\( S^i \)) means the appreciation or revaluation of Chinese (country i’s currency), verse versa. \( W^i \) is the trade weight (percentage) of China’s trader partner i; \( CPI_{\text{China}} \) (\( CPI^i \)) is the consumer price index of China (of the partner country i).

Source: IFS online, IMF (except some ones mentioned below)

CPIs of Taiwan come from National Statistics, R.O.C (Taiwan), (monthly data, 2001=100), we compact them to have the quarterly data and change the base period to 2000.

The exchange rate of Taiwan dollar against the US dollar comes from central bank of Taiwan (monthly data, period average), and we compact them to have the quarterly data.

The exchange rates of euro against US dollar from 1999 first quarter to 2006 second quarter come from Bank of France (monthly data, period average); we do the same to get the quarterly data.

The rates of conversion for French franc, Deutsche Mark, Italian lira and Dutch guilder come from European central bank.

CPIs of China come from Database ChinaInfobank and IFS.

B. Relative price of non-tradable to tradable goods (TNT):

This variable is defined as the ratio of domestic consumer price index (CPI) to the domestic wholesale or producer price index (WPI or PPI) relative to the equivalent foreign effective ratio (trade weighted).

\[
TNT = \frac{CPI_{\text{China}}}{\prod_{i=1}^{N=13} (CPI^i / PPI^i)}
\]

\[
tot = \ln TNT = (\ln CPI_{\text{China}} - \ln PPI_{\text{China}}) - \sum_{i=1}^{N=13} W^i (\ln CPI^i - \ln PPI^i)
\]

\( CPI_{\text{China}} \) (\( CPI^i \)) and \( W^i \) are just the same as defined above, \( PPI_{\text{China}} \) (\( PPI^i \)) is the wholesale or producer price index of China (of the partner country i) according to the availability of the data in each country.

Source: IFS online, IMF (except some ones mentioned below)
PPIs of France are not available until the first quarter 1999, so we use the data extracted from OECD statistics online for the whole period.
PPIs of Taiwan are extracted from come National Statistics, R.O.C (Taiwan), (monthly data, 2001=100); we do

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9 But these rates are not available for each one, for example, the exchange rates of the countries which are the European monetary union members after the birth of Euro; in our example the concerned countries are France, Germany, Italy and Netherlands. In order to obtain their exchange rates from the first quarter 1999 to second quarter 2006, we multiply the exchange rates of Euro against dollar by their conversion rates.


11 The quarterly CPIs from the IFS percentage change relative to the same period of previous year, we calculate the quarterly index (base year = 2000) with these data and yearly data from database Infobank.
the same as for the CPIs of Taiwan. PPIs of China come from Datastream, (monthly data from October 1996 to 2006 June, previous year = 100), we compact them too.

C. Net foreign assets (NFA):

This variable is defined as the stock of net foreign assets, defined as total foreign assets, expressed as a ratio to GDP. In fact, we cannot get the data directly for this variable; instead, we use the ratio of accumulated current account relative to GDP as the proxy to simulate:

$$NFA = \frac{Net\ Foreign\ Asset}{GDP}$$

Following the method suggested by Lane and Milesi-Ferretti (2001): one takes an initial value of the stock of net foreign assets and adds up current account balances to determine the time series, as the proxy of NFA. But in the case of China, we have not even an initial stock, the current account balance data on the quarterly basis either. So that current account balances were added up historically, starting in 1982 to 1993, as the initial stock. Then we use the quarterly trade balances as the proxy of current account balances, and add them cumulatively to the initial stock, finally divide them by GDP.

Source: Trade balances are extracted from IFS online, IFS. Balances of Payments of China (from 1982 to 1993) come from State Administration of foreign Exchange (SAFE), China.

D. Terms of trade (TOT):

$$TOT = \frac{EX_{China}}{IM_{China}} \cdot \prod_{i=1}^{N=13} \left(\frac{EX^i}{IM^i}\right)^{w^i}$$

$EX_{China}$ is the export price index of China (of trade partner country $i$); $IM_{China}$ is the import price index of China (of trade partner country $i$); $w^i$ is the trade weight of country $i$.

$$tot = \ln TOT = (\ln EX_{China} - \ln IM_{China}) - \sum_{i=1}^{N=13} W^i (\ln EX^i - \ln IM^i)$$

$$= (ex_{China} - im_{China}) - \sum_{i=1}^{N=13} W^i (ex^i - im^i)$$

Source: IFS online, IMF (except some ones mentioned below)

$EX_{China}$ and $IM_{China}$ are extracted from the World Development Indicators Database of World Bank (yearly data from 1994 to 2004) and Database DataStream (monthly data from January 2005 to June 2006, previous year = 100).

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13 Chinese current account data was only available on an annual basis, but from 2000, the State Administration of Foreign Exchange (SAFE) of China began to publish the BOP every 6 month.

14 The first Balance of Payments (BOP) of China was compiled in 1982 on the basis of “Balance of Foreign Exchange”.

15 SHI and YU (2005) use this method to get the proxy of NFA, but they take the stock of foreign reserve of 1990 as the initial value of the stock of net foreign assets in the beginning of 1991.

16 We compact the monthly data and interpolate the yearly data in the same way and change their basic period to year 2000 for having a complete time series.
EX and IM of Taiwan are extracted from *National Statistics, R.O.C (Taiwan)*, (monthly data, 2001=100); we transform them in the same way as for the CPIs of Taiwan.

E. Degree of openness (OPEN):

We choose this variable as the proxy of commercial policy as did in the literature, which is defined as:

\[
OPEN = \frac{EXP + IMP}{GDP}
\]

*EXP (IMP)* and *GDP* are the Exportation (Importation) and Gross Domestic Product of China. *EXP (IMP)* and *GDP* are the same like defined above.

*Source:* IFS online (EXP and IMP, current price, expressed in US dollar); GDPs are extracted from Database *ChinaInfobank* (current price, expressed in Yuan), the data are in form of quarterly-accumulated GDP, and so we do some calculation to get the quarterly ones.

F. Trade weights:

The weights calculated in this paper are simple average weights from 1999 to 2001. We calculate the weights according to the ratio of each trade partner country’s foreign trade with China relative to the total foreign trade of these countries with China.

\[
W^i = \frac{Trade^i}{TTrade}
\]

*Trade* is external trade (the sum of exportation and importation) of China with the country *i*; *TTrade* is the total foreign trade of these countries with China. The ratio of the total external trade with these 13 countries is high to 81.6 % in the sample period, and at least 66.3 %.


In Graph5, the evolutions of *reer* and its four economic fundamentals from the first quarter of 1994 to the second quarterly of 2006 are presented.
V. Estimation Results and analysis

A. Stationary analysis

Before testing a cointegration relation among these variables, we must assure that every variable should be integrated with same order. At first, we use the tests of unit root to see if they are stationary. The test of ADF (Augmented Dickey Fuller) and the test of Phillips-Perron are used for the whole period and the results are reports in the Table 1:
Table 1: Tests for unit root

<table>
<thead>
<tr>
<th>Variable</th>
<th>Trend</th>
<th>Intercept</th>
<th>t-Statistics$^a$</th>
<th>Critical Value at 5% or 1%</th>
<th>Classification</th>
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<td><strong>t-Statistics</strong></td>
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<td><strong>Critical Value</strong></td>
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<td><strong>Classification</strong></td>
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<td>$I(0)$, $I(1)$</td>
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<tr>
<th>Augmented Dickey-Fuller Test</th>
<th>Levels</th>
<th>First difference</th>
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<tbody>
<tr>
<td>reer No</td>
<td>No</td>
<td>-0.675090 [2]</td>
</tr>
<tr>
<td>tnt No</td>
<td>No</td>
<td>-3.481667 [1]</td>
</tr>
<tr>
<td>tot No</td>
<td>No</td>
<td>-2.284425 [4]</td>
</tr>
<tr>
<td>NFA Yes</td>
<td>Yes</td>
<td>-1.921752 [1]</td>
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<tr>
<td>OPEN Yes</td>
<td>Yes</td>
<td>-2.934001 [1]</td>
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<th>Phillips-Perron Test</th>
<th>Levels</th>
<th>First difference</th>
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</thead>
<tbody>
<tr>
<td>reer Yes</td>
<td>Yes</td>
<td>-3.718057</td>
</tr>
<tr>
<td>tnt No</td>
<td>No</td>
<td>-3.474015</td>
</tr>
<tr>
<td>tot No</td>
<td>No</td>
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<tr>
<td>NFA No</td>
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</tbody>
</table>

$^a$ Numbers in squared brackets are the numbers of lagged differences (P) used in augmented estimated equation.

For the series NFA and OPEN in level, both the ADF tests and the PP tests do not reject the null hypothesis of a unit root (nonstationary) at the 5 percent. But for tnt, even in the 1 percent, both of two tests reject the null hypothesis (stationary). For the series reer and tot, the two tests report the different results. Here our explanation is that: this difference comes from the small sample (for reer) and the quality$^{17}$ (for tot) of the series. We use the two tests for a longer series of reer and for the series of tot in the period from 1994 to 2004, this time the null hypothesis are not rejected. So we conclude that the reer and tot are not stationary in level. After first differencing of the four nonstationary series, each series rejects the null hypothesis of nonstationary at the 5 percent level.

Evidence from both the ADF tests and the PP tests suggest that there are four variable integrated of the order one, $I(1)$, implying that the series are stationary in the first difference, and one variable integrated of the order zero, $I(0)$, implying that this series is stationary in level. We will interpret it economically in the under section C. Because the series both are $I(0)$ or $I(0)$, so it is possible that there is a cointegration relationship between reer and these four $I(1)$ fundamental variables. The Johansen cointegration test is used to explore this possibility.

B. Johansen cointegration analysis

In order to implement the Johansen cointegration analysis, a VAR in level including these four $I(1)$ variables and the $I(0)$ variable$^{18}$ should be determined with the optimal number of lags in the cointegration analysis. Two criteria are used here to choose the optimal lag length: the Akaike information criterion (AIC), the Schwarz criterion (SC) and Log Likelihood (LL). The AIC and SC statistics from lag 1 to lag 6 in the VAR are reported in Table 2 with an arbitrary choice of a maximum of 6 lag intervals. The statistics in bold is the optimal

---

$^{17}$ As mentioned in the third section, because of shortage of data for tot, we compile the data from World Bank and that from the database DataStream.

$^{18}$ The series included in the VAR is the data from first 1994q1 to 2004q4 for the same reason mentioned above. And because the tnt is $I(0)$, it should be entered in the VAR in level as one exogenous variable of the system.
choice in the VAR specification determined by AIC, SC criteria and LL. The AIC and the SC give the same result: the optimal number of lags is 2; and with the LL, intercept are suggested in the VAR specification.

Table 2: AIC and SC statistics from VAR (1) to VAR (6)

<table>
<thead>
<tr>
<th>Lag intervals</th>
<th>intercept</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIC</td>
<td>Yes</td>
<td>-17.22903</td>
<td><strong>-18.31334</strong></td>
<td>-18.28244</td>
<td>-17.46967</td>
<td>-16.54158</td>
<td>-16.21593</td>
</tr>
<tr>
<td></td>
<td>LL</td>
<td>394.4240</td>
<td>424.5801</td>
<td><strong>430.7900</strong></td>
<td>421.3934</td>
<td>410.5608</td>
<td>412.1026</td>
</tr>
<tr>
<td></td>
<td>LL</td>
<td>393.1527</td>
<td>419.0530</td>
<td><strong>425.6814</strong></td>
<td>414.7469</td>
<td>405.1116</td>
<td>403.3665</td>
</tr>
</tbody>
</table>

Table 3: Johansen’s cointegration test

Unrestricted Cointegration Rank Test

<table>
<thead>
<tr>
<th>Hypothesized No. of CE(s)</th>
<th>Eigenvalue</th>
<th>Trace Statistic</th>
<th>5 Percent Critical Value</th>
<th>1 Percent Critical Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>None **</td>
<td>0.584489</td>
<td>74.72378</td>
<td>53.12</td>
<td>60.16</td>
</tr>
<tr>
<td>At most 1 *</td>
<td>0.352622</td>
<td>37.83744</td>
<td>34.91</td>
<td>41.07</td>
</tr>
<tr>
<td>At most 2</td>
<td>0.309201</td>
<td>19.57477</td>
<td>19.96</td>
<td>24.60</td>
</tr>
<tr>
<td>At most 3</td>
<td>0.091680</td>
<td>4.038676</td>
<td>9.24</td>
<td>12.97</td>
</tr>
</tbody>
</table>

*Hypothesized No. of CE(s): None, At most 1, At most 2, At most 3

*(**) denotes rejection of the hypothesis at the 5%(1%) level
Trace test indicates 2 cointegrating equation(s) at the 5% level
Trace test indicates 1 cointegrating equation(s) at the 1% level

Max-eigenvalue test indicates 1 cointegrating equation(s) at both 5% and 1% levels

C. Analysis of the estimation results

Two cointegration tests are proposed by Johansen for testing the existence of cointegration relationship and the number of cointegrating vectors: the trace test and the Max-eigenvalue test. The estimated values of the trace statistics and the Max-eigenvalue statistics are reported in Table 3. According to the results of the two tests, we conclude that there is one cointegration relation between these 4 variables at 1 percent significance level.

The following equilibrium relationship (with standard error in parenthesis) can be obtained from the Cointegrating vector in the Table 4:
### Table 4: Cointegrating vector

<table>
<thead>
<tr>
<th>REER</th>
<th>TOT</th>
<th>NFA</th>
<th>OPEN</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.000000</td>
<td>-1.296597</td>
<td>-0.279472</td>
<td>0.308235</td>
<td>-2.780879</td>
</tr>
<tr>
<td>(0.15184)</td>
<td>(0.05919)</td>
<td>(0.12141)</td>
<td>(0.04513)</td>
<td></td>
</tr>
</tbody>
</table>

Adjustment coefficients (std.err. in parentheses)

<table>
<thead>
<tr>
<th></th>
<th>D(REER)</th>
<th>D(TOT)</th>
<th>D(NFA)</th>
<th>D(OPEN)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.027441</td>
<td>0.196929</td>
<td>-0.147195</td>
<td>0.026650</td>
</tr>
<tr>
<td></td>
<td>(0.06287)</td>
<td>(0.03502)</td>
<td>(0.07154)</td>
<td>(0.09433)</td>
</tr>
</tbody>
</table>

1. **About the fundamentals**

In this equation, we note that all of the coefficients are correctly signed and all statistically significant. As mentioned in the theoretical section, the fact that the tot and the NFA have the positive effects on the equilibrium rate, and OPEN has a negative effect on real exchange rate is proved empirically. But by contrast, because tot is I(0), it can enter in the cointegrating vector only as a exogenous variable and it means that there is not a cointegrating relation between tot and others variables. In other words, theoretically, not like tot, NFA and OPEN, tot is not a determinant of real exchange rate, for this reason, it does not exist in the equation (11). This is contradictory to the theory. One explanation is that the Balassa effect does not exist in China, so it failed to explain the Chinese exchange rate behaviour. It is also pointed out by other authors (Coudert and couhard, 2004). According to them, the balassa effect is based on some restrictive assumptions that may not be fulfilled in China. For instance, it concerns the perfect mobility of factors of production. Neither sufficient international mobility of capital nor the perfect internal labour mobility exists in china. So the Balassa effect is not verified to affect the evolution of real exchange rate of RMB.

2. **Behavioral Equilibrium Exchange Rate and Misalignment of RMB**

With the cointegration equation (11), we can get the current equilibrium rate and current misalignment. We report them In Graph 6 and 7.

\[
\text{mis\_cur} = (\text{reer} – \text{beer\_cur})/\text{beer\_cur} \tag{12}
\]

mis\_cur is the current misalignment, beer\_cur is the current equilibrium exchange rate.
Just like we mentioned above, the economic fundamentals may not be at their long-run equilibrium level, so in order to get the long-run equilibrium exchange rate, we should at first have the equilibrium value for these fundamentals, and here we use the Hodrick-Prescott Filter to smooth them. Then using the equation (11), we can calculate the long-run equilibrium exchange rate with those equilibrium values of fundamentals. In the same way, the total or long-run misalignments are obtained. We report them in Graph 8 and Graph 9.

\[
mis_{\text{per}} = (\text{reer} - \text{beer}_{\text{per}})/\text{beer}_{\text{per}}
\]

(13)

\(mis_{\text{per}}\) is the long-run misalignment, \(\text{beer}_{\text{per}}\) is the long-run equilibrium exchange rate. When misalignment is superior to zero, it means that \(\text{reer}\) is over-evaluated; when misalignment is inferior to zero, it means that \(\text{reer}\) is under-evaluated.

The results reported in Graph 8 and Graph 9 are basically consistent with that reported in Graph 6 and Graph 7. But we have two points to underline. First one, in the sample period, the \(\text{beer}_{\text{per}}\) is more stable than \(\text{beer}_{\text{cur}}\). Because \(\text{beer}_{\text{cur}}\) is derived from the economic fundamentals in their actual value, which may deviate from their equilibrium levels and represent fluctuations. Secondly, the \(\text{mis}_{\text{per}}\) tell us that the RMB is almost
under-valuated during the majority of the sample period. But the degree of misalignment is very small, the biggest undervaluation is just high to 3.94% in 1999q4, and after the exchange rate regime reform in July 2005, the RMB is over evaluated, but the amplitude is limited to 1%. Because beer_per can better reflect the relation between the permanent equilibrium rate and the economic fundamentals, so we pay more attention to the analysis of Graph 8 and 9.

At first we will clarify the dynamics of the evolution of the beer_per from the beginning of the sample period. From 1994q1 to 1999q3, RMB equilibrium exchange rate has exhibited a steady appreciation, and this is the consequence of co-influence of its economic fundamentals. Precisely, From Graph5, we can see that in this under period tot and NFA have a trend to rise and OPEN tends to decrease. Even though tot began to drop from 1997q4 and OPEN began to soar from 1998q4, which means the beer_per will depreciate, the beer_per continues to rise because it is driven by the growth of NFA caused by the surplus of current accounts of China. The effect of quick growth of NFA compensates the pressure of depreciation given by evolutions of tot and OPEN. But from the 1999q3 to the recent period, the beer_per started to depreciate. This depreciation is represented also by its economic fundamentals. During this under period, the term of trade deteriorates; the rise of net foreign asset position decelerates and the degree of openness became to grow up rapidly.

Graph 10:

As for the fluctuation of the misalignment, it comes from that of REER. From 1994q1 to 1998q1, the reer rises as quickly as beer_per does, there are two principles reasons: the CPI increased from first quarter of 1994 until the second quarter of 1996 (cf graph 10); the shock of the eastern Asian financial crisis made the currencies of the partners countries of China depreciated relative to dollar, so made the reer appreciated because of the peg to the dollar of RMB. After this shock, the REER continued to climb up, even though the there was a deflation after second quarter of 1996. So the under valuation became smaller and smaller, at the first quarter of 1998, the REER is very near to beer_per. From 1998q1, because the currencies of the countries influenced by the Asian financial crisis began to appreciate relative to the dollar, and at the same time, Chinese monetary authorities peg the RMB to the dollar, so the REER of RMB depreciates with a very low inflation rate in China. And From 2002, because of the continual depreciation of dollar and the peg of RMB to the dollar, the REER continues to depreciate until the mid 2005. The exchange rate regime reform in July 2005 makes possible a more flexible regime, and a direct consequence of appreciation of nominal exchange rate of RMB. Plus the rise of CPI of China at the same time, the REER has a trend to rise to the equilibrium level and is a little over-evaluated in the after-reform period.
D. A comparison of estimated results

As one objective of this paper, it is useful to compare our estimated BEERs above with that obtained by Shi and Yu (2005). They estimate the BEERs and the misalignments of RMB from 1991q1 to 2004q3 and the results are reported in Graph 11 and Graph 12. The principal difference is that during their sample period, the beerpermanent has only one trend of appreciation, which is not consistent with our results: beer_per at first has a tendency to appreciate and trends to depreciate. Even though from 1999q3 to 2004q3, we both find an under-period in which the reer of RMB is under-evaluated, but the tendency of evolution of the misalignment is opposite: in Graph 11 and Graph 12, we can see that the reer trends to deviate from its long-run equilibrium level, in other words, the under-evaluation has a tendency to rise, but limit in a small amplitude; our results show that the under-valuation becomes smaller and smaller and the reform of Chinese exchange rate regime correct this misalignment and make it a little over-evaluated.

The principal reason for this difference, according to us, is that we build a database which contains the more precise time series, see the fourth section. We can verify this by other findings: in their paper, tnt is I(1) and not the I(0), it means this variable can enter into the cointegrating vector. After finding a cointegrating relationship beween the fundamentals and the reer, they show that tnt has a positive and statistically significant effect on real
exchange rate, which is the opposite in our paper. Their estimation also shows a negative effect of tot on real exchange rate. It is the third difference between their result and ours. These differences can be explained by the use of different data. But we have a common point, as to the degree of misalignment, with their estimated results, as with the results showed in other papers: the misalignment of RMB is not very high and is limited to 5%.

VI. CONCLUDING REMARKS

In this paper, we employ the behavioral equilibrium exchange rate (BEER) model to estimate the equilibrium real exchange rate of Renminbi and the exchange rate misalignment in China, which covers the period from 1994q1 to 2006q2. Using the most precise and recent data, the main findings of the paper are that (1) the term of trade (tot), the net foreign asset position (NFA) and the degree of openness (OPEN) are the important determinants of long-run equilibrium real exchange rate of RMB. The tot and the NFA have the positive effects on the equilibrium rate, but the OPEN has a negative effect on it; that (2) since 1994q1, RMB equilibrium exchange rate has exhibited a steady appreciation, but from the 1999q3 to the recent period, it started to depreciate. And (3) that RMB real exchange rate has been under-valuated during the most part of sample period, but this misalignment has a trend to become smaller and small, and in recent after-reform period, a small degree of over-evaluation replaces this under-valuation. And we compare our results with that of Shi and Yu, this comparison shows that with newly built database, we obtain the newer and more robust results.

Our results are in some degree consistent with the studies which focus on estimating only the equilibrium exchange rate of RMB: a confirmation of a low degree of misalignment. As for the researches which estimate a group of countries using the panel data, a greater undervaluation of RMB are supported by their results. It is evident to explain this paradox: because of the heterogeneity of the countries in the sample group, the “international standard” is different from the “Chinese standard” without doubt. In this circumstance, our future direction of research is to choose some countries more or less homogeneous, for instance some countries in the same region, and to estimate the equilibrium exchange rate with the panel data. This will give us an inspiration from a new point of view.
References


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