

# Estimate of Equilibrium Real Exchange Rate and Misalignment of Chinese Yuan Vis-a-Vis US Dollar

Atabani Adi Agya<sup>1</sup>, Du Jun<sup>2</sup>

<sup>1,2</sup>*School of Economics, Capital University of Economic and Business, Beijing, China,*  
<sup>1</sup>*E-mail: atabaniadi@yahoo.com,* <sup>2</sup>*E-mail: dujun2001@hotmail.com*

**Abstract** *The paper examines the misalignment in equilibrium real exchange rate of Chinese Yuan against US dollar. The data covered the period of 1980-2014, it used Vector Autoregressive model, the variables are not stationary at level and became stationary after first differencing and there were three co-integration vectors. The long run coefficients have expected sign except for interest rate differential and are significant at 5 percent significance level. The speed of adjustment of real exchange rate to its equilibrium indicated that the disequilibrium in the last period are corrected by 87 percent each year and highly significant. The Yuan was overvalued by 4 percent, from 1981-1990 and in 1990 it was undervalued about 4 percent and move back to equilibrium, the highest overvaluation was in 1993 up to 13 percent from equilibrium value and undervalued in 1994 by 14 percent which was the highest level of undervaluation, between 1996 to 2005 the Yuan was relatively within its equilibrium and slightly overvalued to 3.8 percent in 2008 back to long time path in 2011 and relatively undervalued by 1-3 percent since 2012, in general the Yuan is not substantially undervalued as claims in some studies both theoretical and empirical estimation and the movement in the exchange rate are consistent with economic fundamentals of China.*

**Key words** Equilibrium Exchange Rate, Economic Fundamental, Misalignment, Yuan Vis-a-Vis US Dollar

**JEL Codes:** F31, F41

---

## 1. Introduction

Exchange rate policy is one of the tools used to stimulate desired macroeconomic outcome from internal to external balance in an economy. Chinese economy has experienced remarkable changes in the past 30 to 40 years, its currency (hereinafter, Yuan) has passed different stages of development from fixed, crawling peg to managed floating, the value of the Yuan has moved in the same direction with the economic fundamentals of the economy.

The term equilibrium exchange rate is the rate at which a demand for a currency and supply of the same currency are equal; the equilibrium exchange rate indicates that the price of exchanging two currencies will remain stable or constant over time and as Financial Times put it, as an exchange rate that would take account of differences in inflation, interest rates and other aspects of the economic situation.

Since the adoption of manage floating exchange rate policy the Yuan has been appreciating steadily, despite this development the Yuan has come under increasing attacked by major trading partner of China accusing the government of manipulating the value of Yuan to gain undue advantage in international trade competitiveness. However, one may tend to ask a succinct question that what is the equilibrium or the true value of a currency in general and how do we determine whether or not that a currency is undervalued or overvalued given the policy regime difference across countries. The so-called floating exchange rate adopted by most developed economies as it has been shown that monetary policy has impacted on the force of demand and supply which is believed to be the determining forces that act to bring a currency to equilibrium value in the foreign exchange market.

In 1994 the Yuan was pegged to the US Dollar at 8.28 for more than a decade and in 2005 the Yuan appreciated by 2.1 percent against US Dollar which many commentators attribute to the intense pressure from China trading partner and later introduce a managed float system against a basket of major currencies including the US Dollar. After the change to managed float the Yuan appreciated by about 21 percent to a level of 6.83 to a dollar within three years, this rapid appreciation was short lived as a result of global financial crisis, by December 2013, the Yuan has cumulatively appreciated by 12 percent to 6.11 and it been hovering from 6.20 to 2.21 for almost year based on our observation of exchange rate movement of Yuan against the USD before it depreciated by 2.7 percent to 6.38 due to change in exchange rate policy to be more market base rate and the Yuan has since appreciated relatively.

## 2. Literature Review

Despite the very large volume of empirical research in this area over the last four decades, there is no clear consensus concerning the true value of Chinese Yuan and percentage of misalignment against USD and other major trading partner, For instance, Goldstein (2004) and Frankel (2005) applied fundamental equilibrium RER approach and found at in 2000, the PRC's RER undervalued by 15–25 percent and 35 percent, respectively. Wang (2004), by contrast, applies the BEER approach by including PROD, NFA, and trade policy openness during 1980–2003. No obvious misalignment is found after 1995. However, Cheng and Orden (2005) who apply the BEER approach but include fiscal policy, capital flows, and TOT in 1978–2002, found that the PRC's RER undervalued in 2002 by 22.7 percent. Sato, Shimizu, Nagendra and Zhaoyong (2010) estimate the equilibrium exchange rate (EER) of the Chinese Renminbi (RMB) vis-a-vis the U.S. dollar from 1992 to 2008 they focus on the supply side real factors in estimating the EER by extending the Yoshikawa 1990 model, The results show that the EER of Chinese RMB appreciates sharply from 2005 to 2008. That the current RMB

exchange rate has been substantially undervalued and should be revalue by 65 percent from the year 2000 level. Such sharp appreciation of the EER corresponds to the dramatic increase in China's current account surplus from the mid-2000s, especially against the United States, which is ascribed to the significant improvement of both labor and intermediate input coefficients in China. Rod and Ying (2011) The paper surveys the literature on real exchange rate determination, as well as that addressing the puzzles over the trends in China's real exchange rate. While this was widely expected to appreciate against the advanced economies after China's first growth surge in the mid-1990s, it actually depreciated slightly until the early 2000s. Then, after 2005, its rate of appreciation was more rapid than expected.

Ernest (2003) estimated that the Yuan was undervalued by 40 percent in 2003. While this claim is not based on any formal analysis, he uses several rule-of-thumb estimates to reach this conclusion. His first observation is that the increase in Chinese foreign exchange reserves equaled 100 percent of the Chinese trade surplus less net foreign direct investment (FDI) flows in the first six months of 2002. He concludes that the entire trade surplus less net foreign direct investment would be zero in the absence of the increase in foreign exchange reserves. His second observation is a rule-of-thumb estimate that a 1 percent decline in the dollar leads to a \$10 billion decline in the trade deficit in the United States He then observes that the dollar would need to decline by 40 percent according to that rule of thumb to eliminate the trade deficit since the U.S.

Kefei and Nicholas (2012) investigate the equilibrium real effective exchange rate for the Chinese RMB during the post-reform period, 1982-2010. They extend the NATREX model in several important perspectives and apply it for the first time to China, by constructing quarterly and wide range of fundamental and find that RMB was overvalued against a basket of 14 currencies until mid-1980s. During 1986-2010, it was undervalued in most years except after the Asian financial crisis in 1997. Found persistent undervaluation from 2004 onwards. However, the misalignment rates are much lower than those reported by previous studies and the undervaluation rate actually declined sharply in 2008. The undervaluation rate rose modestly in 2009 and sharply in 2010, though it is still lower than what has been suggested by other studies, Michael and Jorg (2005) finds compelling evidence that the renminbi is not substantially undervalued. In other words, in some circles it appears to have been politically expedient to scapegoat the Chinese currency for economic difficulties elsewhere.

Jim and Dominic (2003) have estimated that the yuan was 9.5-15 percent undervalued in 2003. They argue that the current account less FDI should be zero in equilibrium (which means that China would have a current account deficit equal to FDI), which could be accomplished with a 9.5-15 percent revaluation. Virginie and Cecile (2003) use the most sophisticated analysis to estimate their parameters. They argue that

China has an underlying current account deficit of between 1.5 percent and 2.8 percent of GDP. They estimate that the Yuan was 44-54 percent undervalued against the dollar. Jeff, Wende and David (2008) Using the Beveridge-Nelson decomposition a vector error correction model (VECM) of the exchange rate as a function of macroeconomic fundamentals find that the Chinese Yuan has been fluctuating moderately around its long run equilibrium value with undervaluation up to 4% and overvaluation up to 6 percent at various points in time since 1997. This result is consistent with findings of many of the most recent studies employing alternative econometric methodologies to determine the equilibrium exchange rate. While the Yuan real effective exchange rate has deviated from equilibrium, and it is sticky, taking over five years to correct 50 percent of the short run misalignment, it does not appear to have been consistently undervalued as has been widely argued. Zhang (2002) develops equilibrium real exchange rate (ERER) and behavioral equilibrium exchange rate (BEER) models for RMB by using co-integration analysis, the Hodrick-Prescott (H-P) filter and other econometrics techniques. He shows that the exchange rate of RMB is close to the equilibrium level in 1999. Zhaoyong (1999) assess China's foreign exchange reform and the impact of its currency devaluation on the balance of trade the effect of the real effective exchange rate on the real trade balance appears to be moderate. The dual exchange rate system adopted in the mid-1980s, mitigated the impact of the exchange rate unification, and facilitated the move towards an equilibrium level of exchange rate.

Base on the foregoing it is obvious that there are lot of controversies in the literature while must work used effective real exchange rate to evaluate bilateral exchange rate value, this is the bane of such studies and other study particular from developed nations base they judgment on intuition instead of empirical evidence. It also appears a divide between researcher from American and China as the empirical or theoretical result are countering each other across the divide. In other hand even the few studies that used bilateral exchange rate are nominal value which is not a good measure for comparison. Hence the need for this work to shade light on this topic and enrich the literature of equilibrium real exchange rate and misalignment of real exchange rate in China.

### **3. Methodology of research**

The natural real exchange rate (hereafter refers as NATREX) approach offers an alternative paradigm for equilibrium real exchange rates. The NATREX is the equilibrium real exchange rate that simultaneously assures both the goods market and balance-of-payments equilibrium. Allen (1995) and Stein (1994) developed the NATREX models to test empirically whether movements in quarterly real exchange

rates can be explained by changes in exogenous real fundamentals. Their fundamental disturbances are exogenous changes in thrift and productivity at home and abroad and for small countries, changes in the terms of trade and world real interest rate. This paper employed Vector Auto-regression method developed by Johansen (1988), and Johansen and Juselius (1990) to determine the relationship between real exchange rate and it fundamentals variables (PROD, DISRAT, USDISRAT, TOT, INTDIFF). This can be stated in econometric forms thus:

$$LREXR_t = \sum_{-1}^n \alpha_1 LPROD_{t-1} + \beta_1 LREXR_{t-1} + \gamma_1 LDISRAT_{t-1} + \delta_1 LUSDISRAT_{t-1} + \lambda_1 LTOT_{t-1} + \phi_1 INTDIFF_{t-1} + u_t \quad (1)$$

$$LPROD_t = \sum_{-1}^n \alpha_2 LREXR_{t-1} + \beta_2 LPROD_{t-1} + \gamma_2 LDISRAT_{t-1} + \delta_2 LUSDISRAT_{t-1} + \lambda_2 LTOT_{t-1} + \phi_2 INTDIFF_{t-1} + u_t \quad (2)$$

$$LDISRAT_t = \sum_{-1}^n \alpha_3 LREXR_{t-1} + \beta_3 LDISRAT_{t-1} + \gamma_3 LPROD_{t-1} + \delta_3 LUSDISRAT_{t-1} + \lambda_3 LTOT_{t-1} + \phi_3 INTDIFF_{t-1} + u_t \quad (3)$$

$$LUSDISRAT_t = \sum_{-1}^n \alpha_4 LREXR_{t-1} + \beta_4 LUSDISRAT_{t-1} + \gamma_4 LPROD_{t-1} + \delta_4 LUSDISRAT_{t-1} + \lambda_4 LTOT_{t-1} + \phi_4 INTDIFF_{t-1} + u_t \quad (4)$$

$$LTOT_t = \sum_{-1}^n \alpha_5 LREXR_{t-1} + \beta_5 LTOT_{t-1} + \gamma_5 LDISRAT_{t-1} + \delta_5 LUSDISRAT_{t-1} + \lambda_5 LPROD_{t-1} + \phi_5 INTDIFF_{t-1} + u_t \quad (5)$$

$$INTDIFF_t = \sum_{-1}^n \alpha_6 LREXR_{t-1} + \beta_6 INTDIFF_{t-1} + \gamma_6 LDISRAT_{t-1} + \delta_6 LUSDISRAT_{t-1} + \lambda_6 LTOT_{t-1} + \phi_6 LPROD_{t-1} + u_t \quad (6)$$

Where:

LREXR is the logarithm of Real exchange rate of Yuan against US Dollar, LPROD is the logarithm of China Productivity, LDISRAT is the logarithm of China discount rate, LUSDISRAT is the logarithm of US discount rate, LTOT is the logarithm of China Term of trade and INTDIFF is the interest rate differential between China and US.

To estimate the VAR we have to determine whether or not the variables involve are stationary or otherwise. We used Unit root test developed by Dickey and Fuller (1979) given by the following three equations dependent on the nature of the variables:

$$\Delta y_t = \alpha + \delta y_{t-1} + \sum_{i=1}^m \beta_i \Delta y_{t-i} + \varepsilon_t \quad \text{Test with constant} \quad (7)$$

$$\Delta y_t = \alpha + \beta t + \delta y_{t-1} + \sum_{i=1}^m \beta_i \Delta y_{t-i} + \varepsilon_t \quad \text{Test with constant and trend} \quad (8)$$

$$\Delta y_t = \delta y_{t-1} + \sum_{i=1}^m \beta_i \Delta y_{t-i} + \varepsilon_t \quad \text{Test with none} \quad (9)$$

Where:

$\Delta$  denotes the first difference,  $y_t$  is the time series being tested,  $t$  is the time trend, and  $m$  is the number of lags which are added to the model to ensure that the residuals,  $\varepsilon_t$  are white noise.

The difference between equation (1) and (2) is that the first equation includes just drift. However, the second equation includes both drift and linear time trend. This paper also employs the Philip-Perron test, Phillips (1987) and Phillips and Perron (1988). Since the possibility of the presence of structural breaks makes the ADF test unreliable for testing unit root the presence of a structural break will tend to bias the ADF test towards non-rejection of the null hypothesis of a unit root. The regression equation for the PP test is given by:

$$\Delta y_t = \alpha + \beta y_{t-1} + \varepsilon_t \quad (10)$$

### 3.1. Co-integration test

The test for Co-integration is the necessary step in order to determine if the variables have a long-run relationship; the idea of using co-integration techniques in the study of non-stationary time series was first introduced by Granger (1981) and advanced by (Granger and Weiss, 1983; Engle and Yoo, 1987; Engle and Granger, 1987; Johansen, 1988; and Johansen and Juselius, 1990). Co-integration theory provides a unified framework for examining the long-run equilibrium relationship and short-run dynamic behaviour existing between two (or more) non-stationary economic time series. In order to test for co-integration, the multivariate maximum likelihood co-integration technique proposed by Johansen (1988) is employed in this paper. It fully captures the underlying time series properties of the data, provides estimates of all of the co-integrating vectors that exist among a vector of variables, and offers a test statistic for the number of co-integrating vectors. A further advantage of employing the Johansen technique is that it allows direct hypothesis tests on the coefficients entering the co-integrating vectors. This can be stated generally for unrestricted vector Auto-regression thus:

$$Y_t = \pi_1 Y_{t-1} + \dots + \pi_k Y_{k+1} + \mu + e_t \quad (11)$$

Where;

$\pi$  is an  $(n \times n)$  matrix whose rank determines the number of distinct co-integrating vectors that exist among the variables in  $(n \times 1)$  vector  $Y_t$ . If the rank of  $\pi$  matrix is zero, each element of  $\pi$  must equal zero. For co-integration to exist the rank of the  $\pi$  matrix has to be greater than zero and less than  $n$  that is  $0 < r_n < n$ , where  $r_n$  is the number of co-integrating vectors in vector  $Y$  and  $n$  is the number of variables contained in the vector  $Y$ . If the rank of  $\pi$  matrix, denoted as  $\text{rank}(\pi)$ , equals one, there is a single co-integrating vector, on the hand if  $1 < \text{rank}(\pi) < n$ , there are multiple co-integrating vectors. When  $0 < r_n < n$ .

In Maximum likelihood Co-integration approach; we used trace and the Maximum Eigen-value, both can be used to determine the number of co-integrating vectors, they

don't always indicate the same number of co-integrating vectors. The distribution of both tests statistics is non-standard. The Trace test is a joint test with null hypothesis of number of co-integrating vectors is less than or equal to  $r$ , against alternative hypothesis that there are more than  $r$  co-integrating vectors. The Maximum Eigen-value test conduct separate tests on each Eigen-value with null hypothesis that there are  $r$  co-integrating vectors exist against the alternative hypothesis that there exists  $(r+1)$ . However, whenever the result of the two tests shows different co-integration vectors we go with the trace test in estimating the error correction model. These tests are given as follows:

$$LR_{\max}(r / r + 1) = -T \ln(1 - \hat{\lambda}_{r+1}) \quad (12)$$

Where

$\lambda_1, \dots, \lambda_n$  denote  $n$  squared canonical correlations between the  $Y_{t+k}$  and  $\Delta Y_t$  series corrected for the effect of the lagged differences of the  $Y$  process. Furthermore, the number of distinct co-integrating vectors is shown to be equal to the number of non-zero  $\lambda$ 's. Thus, the likelihood ratio statistic for the null hypothesis of at most  $r$  co-integrating vectors-the trace statistic is given by

$$LR_{tr}(r/k) = -T \sum_{i=r+1}^k \ln(1 - \hat{\lambda}_i) \quad (13)$$

Johansen methodology direct hypothesis tests of the characteristic roots of the  $\pi$  matrix that are statistically different from zero. That is, we can determine how many Eigen-values differ significantly from zero. This can be conducted by using equation 9, known as TRACE statistic.

Where

$\lambda_i$  = the estimated characteristic roots (Eigen-values) obtained from the estimated  $\pi$  matrix.

$T$  = number of observations;

$r$  = number of co-integrating vectors under the null hypothesis.

The TRACE statistic tests for at most  $r$  co-integrating vectors among a system of  $n > r$  time series (Johansen, 1988). The TRACE statistic has nonstandard distributions under the null hypothesis, so the approximate critical values have been tabulated by Johansen and Juselius (1990).

According to Granger (1981) co-integration theorem for any order one  $I(1)$  series, so long as there is long run relationship there must be Error correction model in the short run to bring series back to the long run path.

Equation 11 can be generalized for Dynamic model (Error correction model) as follows; Given  $(n+1)$  vector  $Y_t = (Y_{1t}, Y_{2t}, \dots, Y_{nt})$  has an error correction representation, if it can be expressed in this form;

$$\Delta Y_t = \Pi_0 + \Pi_1 Y_{t-1} + \Pi_1 \Delta Y_{t-1} + \Pi_2 \Delta Y_{t-2} + \dots + \Pi_p Y_{t-p} + e_t \quad (14)$$

Where:

$\Pi_0$  An  $(n+1)$  a vector of intersect terms;

$\pi$  is a matrix with elements such that one or more of the  $\pi_{jk} \neq 0$ ;

$\pi_i = (n \times n)$  coefficients matrices with elements  $\pi_{ji(i)}$ ;

$e_t$  = an  $(n \times n)$  vector with elements  $e_{it}$ .

We can define two  $n \times r$  matrices such that  $\pi = \alpha\beta'$  where  $\beta$  is a matrix of co-integrating vectors and  $\alpha$  is a matrix of error correction coefficients. The rows of  $\beta'$  form the  $r$  distinct co-integrating vectors, such that, if  $\beta'_i$  is the  $i$ th row of  $\beta'$  then  $\beta'_i Y_t \sim I(0)$ .

### 3.2. Lag Length selection Criteria

The sequential modified likelihood ratio (LR) test is carried out as follows. Starting from the maximum lag, test the hypothesis that the coefficients on lag are jointly zero using the statistics:

$$LR = (T-m) \{ \log | \Omega \ell^{-1} | - \log | \Omega \ell | \} \sim \chi^2(k^2).$$

Where  $m$  is the number of parameters per equation under the alternative. Note that we employ Sims' (1980) small sample modification which uses  $(T - m)$  rather than  $T$ . We compare the modified LR statistics to the 5% critical values starting from the maximum lag, and decreasing the lag one at a time until we first get a rejection.

### 3.3. Data description and source

Real exchange rate (*REXR*) is the nominal exchange rate (USD per Chinese Yuan) plus consumer price indices of China minus US consumer price indices

(**Source:** *World Development Indicators, World Bank*).

Discount rate is the rate of social time preference, which is measured by the ratio of social consumption (private consumption plus government consumption) to GNI of each country.

(**Source:** *World Development Indicators, World Bank*).

Real interest rate differential (*INTDIFF*) is the home country's real long term interest rate minus the foreign country's real long term interest rate.

(**Source:** *World Development Indicators, World Bank*).



Terms of trade (*TOT*) of a country is the ratio of the weighted average price of its exports to the weighted average price of its imports.

(*Source: World Development Indicators, World Bank*).

Productivity (*PROD*) is measured by the GDP per total employed person in China.

(*Source: World Development Indicators, World Bank*).

All variables are converted to natural logarithm except for interest rate differential.

### 3.4. Apriori expectation explanation

1. The productivity of home country, relative to that of foreign country, is expected to change real exchange rate. When productivity advances more rapidly in home country's traded goods sector than in its non-traded goods sector, productivity growth at home in excess of that abroad will raise the price of non-traded goods sector relative to traded goods sector more at home than in foreign country, appreciating the home country's equilibrium real exchange rate. Exactly opposite happens when foreign country's productivity rises, it depreciates the home currency, implying that  $\beta_1$  is expected to have a positive sign.

2. A rise in the home discount rate lowers domestic savings, raising domestic interest rate, which in turn produces net long term capital inflows into the home country. This appreciates the real exchange rate in the medium term. But the effect is opposite in the long term. The rise in discount rate leads to a rise in foreign debt, which reduces wealth and thus consumption. Thereby, savings rise and the situation is reversed. In other words, the real exchange rate gradually depreciates in the long term, and a number of empirical studies have supported this long term view of depreciation of real exchange rate in response to an exogenous rise in home discount rate. Therefore,  $\beta_2$  is expected to be negative. For opposite reasons,  $\beta_2$  is expected to be positive and  $\beta_3$  is expected to be negative.

3. Whether an improvement in a country's *TOT*, i.e., a rise in the price of its exports relative to the price of imports will lead to a rise or fall in the real equilibrium value of that country's currency depends upon that country's share of imports in total consumption, relative to the foreign country's share of imports in their total consumption. If the share of imports in consumption is lower in the home country, real exchange rate appreciates with an improvement in *TOT*, else it depreciates. Therefore, the sign of  $\beta_4$  is ambiguous.

4. In a world where capital is permitted to flow freely across national borders, a rise in home real interest rate relative to foreign real interest rate attracts foreign capital into the home market. The resulting increase in demand for domestic currency will

contribute to an appreciation of the real exchange rate. Therefore,  $\beta_5$  is expected to be positive.

#### 4. Data Presentation and Analysis

Table 4.1. Unit Root Test Result

Variables	ADF C & T	Critical Value (5%)	PP C & T	Critical Value (5%)	Result
LREXR	-1.527591 (0.7971)	-3.568379	-0.966921 (0.9356)	-3.548490	$I(1)$
LPROD	-0.926406 (0.7670)	-2.954021	-1.152046 (0.9045)	-3.548490	$I(1)$
LTOT	-1.667629 (0.7436)	-3.548490	-1.852321 (0.6568)	-3.548490	$I(1)$
LDISRAT	-1.123132 (0.6909)	-2.981038	-1.438123 (0.8309)	-3.548490	$I(1)$
RIDIFF	-1.643697 (0.4493)	-2.957110	-3.332832 (0.0781)	-3.548490	$I(1)$
LUSDISRAT	-2.804102 (0.2059)	-3.552973	-2.657561 (0.2593)	-3.548490	$I(1)$
<b>1<sup>st</sup> difference</b>					
LREXR	-7.254923 (0.0000)	-1.951332	-7.104992 (0.0000)	-1.951332	$I(0)$
LPROD	-2.121315 (0.0344)	-1.951332	-4.358385 (0.0016)	-2.954021	$I(0)$
LTOT	-5.617756 (0.0000)	-1.951332	-5.668467 (0.0000)	-1.951332	$I(0)$
LDISRAT	-3.557909 (0.0146)	-2.986225	-3.700070 (0.0005)	-1.951332	$I(0)$
RIDIFF	-6.350417 (0.0000)	-1.951332	-9.127733 (0.0000)	-1.951332	$I(0)$
LUSDISRAT	-5.903357 (0.0000)	-1.951332	-5.992789 (0.0000)	-1.951332	$I(0)$

**Note:** Figures within parenthesis indicate Mackinnon (1996) one-sided p-value. 5% critical value for rejection of hypothesis of unit root applied.

**Source:** Author's estimation.

Table 4.1 Shows that all the variables have unit root at level, this can be seen by comparing the computed values (in absolute terms) of both the ADF and PP test statistics with the critical values (also in absolute terms) at 5 percent level of

significance. Result from table 4.1, provides strong evidence of unit root in the variables.

Therefore, the null hypothesis can't be rejected and we can safely say the variable are integrated of order one  $I(1)$ , it is sufficient to conclude that there is a presence of unit root in the variables at levels, following from the above result, all the variables were differenced once and both the ADF and PP reveals that all the variables became stationary at first difference, this can be seen by comparing the test statistics and the critical value as presented in 4.1 where the test statistics is greater that the critical value at 5% significance. Hence, the null hypothesis of unit root at first difference is rejected and we can safely conclude that the variables became stationary after first difference. This implies that the variables are integrated of order one, that is  $I(1)$ .

*Table 4.2. Akaike Information Critical (AIC); Multivariate VAR*

VAR Model	AIC				
	1	2	3	4	Optimal lag length
LREXR-Fundamental	-28.36370	-29.77895	-31.06062	-44.55577	4*

**Source:** *Author's estimation*

Table 4.2 show the maximum lags of four is the preferred lag in the unrestricted VAR model to be use in the estimate of long run coefficient and short run dynamics of the VAR/VEC model in our analysis.

#### 4.1. Co-integration Test Result

Having established that the variables are integrated of order one  $I(1)$ , we proceed to determine the co-integration or otherwise among the variables, when co-integration relationship exist it means that real exchange rate, discount rate, Term of trade, real interest rate differential, US Discount Rate, China productivity has a common trend and long run relationship as suggested theoretically. We employed Johansen Co-integration test.

Table 4.3 Show the result of co-integration test, the null hypothesis that no co-integration of  $r=0$  and  $r \leq 1$ ,  $r=1$  and  $r \leq 2$ , and  $r=2$  and  $r \leq 3$  in the model was reject in the trace statistics and  $r \leq 2$  can't be rejected in maximum Eigen value statistics. The statistical value of these tests were greater than the critical values, however, the null hypothesis, that  $r \leq 4$  could not be rejected in the trace statistics because the values were less than the critical values implying that there are at less three co-integrating

vector among the series. Normally when the result of the trace test differs with the maximum eigenvalue, trace test are implemented. The implication of this result is that there exists a long-run relationship among the series. We present the long run parameters as represented in the first normalized coefficient in the co-integration test results.

Table 4.3. Co-integration Test Result

**Unrestricted Co integration Rank Test (Trace)**

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.898555	177.5775	103.8473	0.0000
At most 1 *	0.767660	104.3537	76.97277	0.0001
At most 2 *	0.568855	57.64795	54.07904	0.0232
At most 3	0.416585	30.72599	35.19275	0.1401
At most 4	0.225531	13.48259	20.26184	0.3265
At most 5	0.152745	5.304105	9.164546	0.2517

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level

\* denotes rejection of the hypothesis at the 0.05 level

\*\*MacKinnon-Haug-Michelis (1999) p-values

**Unrestricted Cointegration Rank Test (Maximum Eigen value)**

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.898555	73.22375	40.95680	0.0000
At most 1 *	0.767660	46.70578	34.80587	0.0012
At most 2	0.568855	26.92196	28.58808	0.0803
At most 3	0.416585	17.24340	22.29962	0.2189
At most 4	0.225531	8.178483	15.89210	0.5265
At most 5	0.152745	5.304105	9.164546	0.2517

Max-eigen-value test indicates 2 co-integrating eqn(s) at the 0.05 level

\* denotes rejection of the hypothesis at the 0.05 level

\*\*MacKinnon-Haug-Michelis (1999) p-values

**Source:** Author's estimation

Table 4.4. Normalized co-integrating coefficient: 1 co-integration equation

Normalized cointegrating coefficients (standard error in parentheses)						
LREXR	LGDP	LDISRAT	LUSDISRAT	LTOT	RIDIFF	C
1.000000	-25.61966	-7.556872	23.39713	3.620264	0.071399	102.5670
	(1.99638)	(1.32523)	(4.00600)	(0.37087)	(0.00945)	(8.54696)
	[12.86]	[5.71]	[5.84]	[9.78]	[7.89]	[12.06]

**Note:** C = Linear trend in the data and an intercept but no trend in the cointegrating equation.

\* denotes significance at 5% significance level.

The figures in first row are normalized cointegrating coefficients. The figures in parentheses are standard error (second row) and figure in bracket are T-statistics (third row) Since all variable are on the same side we reverse the sign on each variable and compared with our a priori expectation.

**Source:** Author's estimation

The result in Table 4.4 is stated thus;

$$LREXR = -103 + 26LGDP + 8LDISRAT - 23LUSDISRAT - 4LTOT - 0.1RIDIFF$$

The result shows the long run coefficient of all the variable used in equation 11 above, all has expected sign except for interest rate differential which sign is not as expected and this is not a surprise as capital account control in China might be the reason for the opposite sign and all the variables are significant at the 5 percent significance level chosen, it means that a 1 percent increase in productivity in China will lead to 25 percent appreciation of the Yuan, 1 percent rise the discount rate in china the Yuan would appreciate by 8 percent, 1 percent rise in US discount rate will cause the Yuan to depreciate 23 percent, 1 percent decrease in terms of trade will lead to 4 percent depreciation of Yuan and 1 percent rise in real interest rate differential will lead 0.1 percent depreciation of the Yuan all other things been equal.

Table 4.5. Speed of Adjustment coefficients

Error Correction:	D(LREXR)	D(LGDP)	D(LDISRAT)	D(LUSDISRAT)	D(LTOT)	D(RIDIFF)
CointEq1	-0.876677	0.050672	0.037346	-0.012829	-0.040548	-16.23046
	(0.30482)	(0.02666)	(0.03470)	(0.03491)	(0.10338)	(24.2647)
	[-2.87605]	[1.90099]	[1.07636]	[-0.36747]	[-0.39221]	[-0.66889]

The figures in first row are speed of adjustment coefficients. The figures in parentheses are standard error (second row) and figure in bracket are T-statistics (third row)

$X^2_{n1}=35.31718(0.0004)$   $X^2_{n7}=604.3427(0.3115)$

**Source:** Author's estimation

Table 4.5 present the speed of adjustment coefficient base on the vector error correction Model for the Yuan-USD real exchange rate, the sign of the speed of adjustment coefficients of real exchange rate of Yuan-USD (LREXR) is negative reinforcing co-integration, US discount rate, term of trade, Real interest rate differential all converge to their long run equilibrium and real exchange rate of USD-Yuan is significant while US discount rate, term of trade, Real interest rate differential are insignificant and China productivity and it discount rate are diverging further away from their long run equilibrium and insignificant, this implies that for every disequilibrium of the Real exchange rate of Yuan-USD in the last year, 87 percent of the disequilibrium in the last period are corrected each year, 1.3 (0.050 x 25.619) percent of the previous year disequilibrium are corrected by China productivity, 0.28 (0.037 x 7.557) percent of the previous year disequilibrium are corrected by China discount rate, 0.28 (0.012 x 23.397) percent of the previous year disequilibrium are corrected by US discount rate, 0.003(0.040x0.071) percent of the previous year disequilibrium are corrected by China terms of trade and 1.6 (0.0668 x 0.071) percent of the previous year disequilibrium are corrected by real interest rate differential between China and US. To determine the proportion of disequilibrium that is eliminated by movements in other variables, its speed of adjustment coefficient must be multiplied by its coefficient in the co-integrating equation.

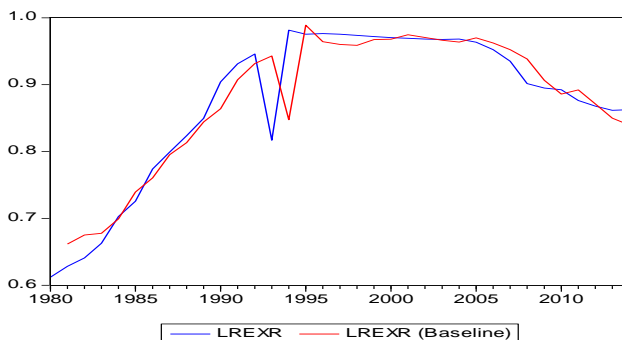


Figure 1. Graph of Actual and Estimated Equilibrium Real Exchange rate

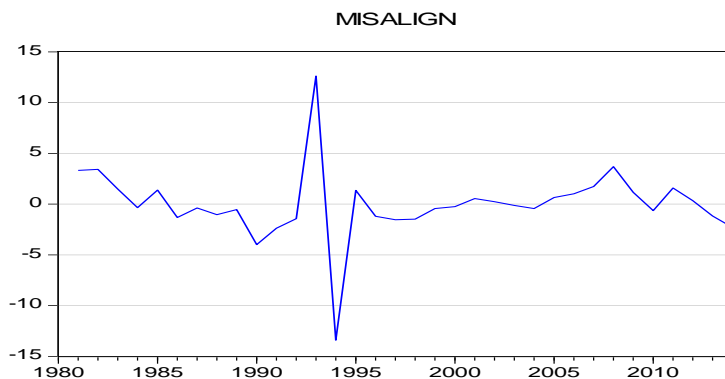
**Source:** Author's estimation

After the estimation of the VAR/VECM, we carry out stability test to determine whether the model is stable, The estimated VAR is stable, if all roots have modulus less than one and lie inside the unit circle it implies our model is stable, If the VAR/VEC is not stable, impose response standard error are not valid, the test for no serial correlation

(autocorrelation) up to twelve (12) lags were accepted, it implies the model is free from autocorrelation in that order respectively, the residual is homoskedastic with p-value of 0.3115 however, the residual are not normality distributed with a p-value of 0.0004 and the impose response show indeed the model is stable.

Figure 1 show the graph of actual real exchange rate plotted together with estimated real equilibrium exchange rate, we compared the value with the actual LREXR as the graph depict the path of the Actual and equilibrium real exchange, this shows that there is no substantial under or overvaluation of the Yuan during period of this study except in 1993 where the Yuan was overvalued and undervalued in 1994 with both fall short of 15 percent of the real equilibrium path during this study.

Figure 2. Actual Misalignments in Percentage



**Source:** Author's estimation

Figure 2 shows the actual misalignment in percentage from the graph the misalignment stating from 1981 was overvalued by 4 percent and quickly move back to equilibrium in 1984 and hover round the equilibrium till 1990 were it was undervalued to 4 percent and move back to it equilibrium, we witness the highest overvaluation in 1993 of up to 13 percent of it real value and quickly undervalued again in 1994 by 14 percent which was the highest level of undervaluation, between 1996 to 2005 the value of Yuan was relatively within it equilibrium and slightly over value to 3.8 percent in 2008 and moved back to it long time path in 2011 and relatively undervalued from 1-3 percent since 2012 to date.

## 5. Conclusions

The task of this paper is to determine the misalignment in equilibrium real exchange rate of Chinese Yuan against US dollar. The data used covered the period of 1980-2014, using Vector Autoregressive co-integration test procedure developed by Johansen (1988), the unit root result shows that variables were not stationary at level and became stationary at first differenced and are integrated of order one  $I(1)$  and the Johansen's co-integration test shows three co-integration vector in the trace and two in Maximum eigenvalues. A long run relationship exist among real exchange rate and it fundamentals (China Productivity, China Discount rate, US discount rate, term of trade and real interest rate differential). The long run coefficient show all the variable has expected sign except for interest rate differential which sign is not as except and this is not a surprise as capital account control in China might be the responsible for the opposite sign, all the variables are significant at the 5 percent significance level, it means that a 1 percent increase in productivity in China will lead to 26 percent appreciation of the Yuan, 1 percent rise in the discount rate in china the Yuan would appreciate by 8 percent, 1 percent rise in US discount rate will cause the Yuan to depreciate 23 percent, 1 percent decrease in term of trade will lead to 4 percent depreciation in Yuan and 1 percent rise in real interest rate differential will lead to 0.1 percent depreciation of the Yuan.

The error correction Model for the Yuan-USD real exchange rate, the speed of adjustment of real exchange rate of Yuan-USD (LREXR), US discount rate, term of trade, Real interest rate differential all converge to their long run equilibrium and real exchange rate of Yuan-USD is significant while all other variables are insignificant and China productivity and it discount rate are diverging further away from their long run equilibrium and insignificant, this implies that for every disequilibrium of the Real exchange rate of Yuan-USD in the last year, 87 percent of the disequilibrium in the last period are corrected each year and highly significant.

The Yuan in 1981 was overvalued by 4 percent and quickly move back to equilibrium in 1984 and hover around the equilibrium till 1990 were it was undervalued to 4 percent and move back to it equilibrium, we witness the highest overvaluation in 1993 up to 13 percent away from equilibrium value and quickly undervalued again in 1994 by 14 percent which was the highest level of undervaluation, between 1996 to 2005 the value of Yuan was relatively within it equilibrium and slightly overvalued to 3.8 percent in 2008 back to long time path in 2011 and relatively undervalued by 1-3 percent since 2012, in general the Yuan is not substantially undervalued as claims in some quarters and the movement in the exchange rate are consistent with Chinese economic fundamentals.



## References

- Cheng, F., Orden, D., (2005). "Exchange Rate Misalignment and Its Effects on Agricultural Producer Support Estimate: Empirical Evidence from India and China." Markets, Trade and Institution Division (MTID) Discussion Paper No. 81, International Food Policy Research Institute, Washington, DC.
- Dickey, D.A., Fuller, W.A. (1979). "Distribution of the Estimators for Autoregressive, time series with a Unit Root." *Journal of the American Statistical Association*. Vol. 74, pp. 427-431.
- Engle, R., Yoo, B., (1987). "Forecasting and Testing in co-integrated Systems." *Journal of Econometrics*, Vol. 35, pp. 143-159.
- Engle, R., Granger, C.W.J., (1987). "Cointegration and Error Correction: Representation, Estimation, and Testing." *Econometrica*, Vol. 55, No. 2, pp. 251-276.
- Frankel, J.A., (2005). "On the Renminbi: The Choice between Adjustment under a Fixed Exchange Rate and Adjustment under A Flexible Rate." NBER Working Paper 11274, National Bureau of Economic Research, Cambridge.
- Goldstein, M., (2004). "Adjusting China's Exchange Rate Policies". Peterson Institute Working Paper Series 04-1, Institute for International Economics, Washington, DC.
- Granger, C.W.J., (1981). "Some Properties of Time Series Data and their Use in Econometric Model Specification." *Journal of Econometrics*, Vol. 16, pp. 121-130.
- Granger, C.W.J., Weiss, A.A., (1983). *Time Series analysis of Error Correction Models*, In S. Karlin, T. Amemiya and L.A. Goodman eds., *Studies in Economic Time Series and Multivariate Statistics*, New York: Academic Press.
- Jim, O'N. Dominic, W., (2003). "How China Can Help the World." Goldman Sachs Global Economics Paper 1997, September 17.
- Jeff, C., Wende, D., & David, K., (2008). "Yuan Real Exchange Rate Undervaluation, 1997-2006. How Much, How Often? Not Much, Not Often." William Davidson Institute, at the University of Michigan, Working Paper Number 934. August 2008.
- Johansen, S., Juselius, K., (1990). "Maximum Likelihood Estimation and Inference on Co-integration- with Applications to Demand for Money," *Oxford Bulletin of Economics and Statistics*, Vol. 52, No. 2, pp.169-210.
- Johansen, S., (1988). "Statistical Analysis of Co-integration Vectors." *Journal of economic Dynamics and Control*, Vol. 12, pp. 231-254.
- Kefej, Y., Nicholas, S., (2012). "Structural Breaks and the Equilibrium Real Effective Exchange Rate of China: A NATREX Approach." *JEL Classification: F31, F32, F41, C51, C52, O53*, pp. 1-44.

- Michael, F., Jorg, R., (2005). "Just How undervalued is the Chinese Renminbi?." *The World Economy*, Vol. 28, pp.465-489.
- Phillips, P.C.B., Perron, P., (1988). "Testing for a unit root in time series regression." *Biometrika*, Vol. 75, pp. 335-346.
- Phillips, P.C.B., (1987). "Time Series Regression with a Unit Root." *Econometrica*, Vol. 55, pp. 277-301.
- Rod, T., Ying, Z., (2011). "Real Exchange Rate Determination and the China puzzle." Western University of Austria, JEL: C68, E27, E65, F31, F41, F43, O11, Australian research Council Discussion Paper 14.19.
- Sims, C. A., (1980). "Comparison of Interwar and Postwar Business Cycles; Monetarism Reconsidered." *The American Economic Review*, Vol. 70, pp. 250- 257.
- Sato, K., Shimizu, J., Nagendra, S., & Zhaoyong, Z., (2010). "New Estimates of the Equilibrium Exchange Rate: The case for the Chinese Renminbi." The Research Institute of Economy, Trade and Industry, <http://www.rieti.go.jp/en/>, REITI Discussion paper series 10-E-045 Paper Series 10-E-045, pp. 1-24.
- Wang, T., (2004). "Exchange Rate Dynamics." In E. Prasad, ed., *China's Growth and Integration into the World Economy: Prospects and Challenges*. IMF Occasional Paper No. 232, International Monetary Fund, Washington DC.
- Zhang, Z., (2002). "Real Exchange Rate Behaviour under Hong Kong's Linked Exchange Rate System: An Empirical Investigation." *International Journal of Theoretical and Applied Finance*, Vol. 5, No. 1, pp. 55–78.
- Zhaoyong, Z., (1999). "Foreign Exchange Rate Reform, the Balance of Trade and Economic Growth: An Empirical Analysis for China." *Journal of Economic Development*, Vol. 24, No. 2, pp. 143-162.