How Is the RMB Exchange Rate Misaligned?
A Recent Application of Behavioral Equilibrium
Exchange Rate (BEER) to China

Yuming Cui
Graduate School of Asia-Pacific Studies, Waseda University
cuiyuming@fuji.waseda.com

The aim of this paper is to estimate the degree of RMB misalignment from its equilibrium exchange rate by applying the Behavioral Equilibrium Exchange Rate (BEER) approach. We employ monthly data with reference to China's top 20 trading partners covering the period of 1997 to 2012. We find that the RMB was slightly overvalued before 2001 and significantly undervalued by up to 20 per cent in the end of 2006. There is evidence showing that the RMB approached to its equilibrium level from 2007 to 2008. However, the global financial crisis interrupted the trend of declining misalignment of RMB exchange rate. The RMB's total misalignment increased to around 25 per cent in the mid-2011 mainly because the RMB was re-pegged to the US dollar and some currencies of China's main trading partners depreciated during the period of crisis. More recently, the degree of RMB misalignment slightly declined since 2012 when the RMB proceeded to appreciate and China's ratio of current account surplus to GDP dropped considerably. Our findings prove that there is a trend of the RMB approaching to its equilibrium exchange rate since 2007 except for the period of crisis.

Keywords: China, RMB, Exchange Rate, Behavioral Equilibrium Exchange Rate
          (BEER), Misalignment
JEL Classification: C32, F31, F41

I. Introduction

Over the last several decades, we have witnessed that exchange rate policy has played an increasingly important role in the development of global economy. Diverse exchange rate regimes were applied by countries[1]. However, recent

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[1] According to Classification of Exchange Rate Arrangements and Monetary Frameworks of the IMF, categories of exchange rate arrangement include: Exchange arrangement with no separate legal tender, Currency board arrange, Other conventional fixed peg arrangement, Pegged exchange rate

global financial crisis triggered lively discussions on "Currency War"[2] which means that countries competitively devalue their currencies so as to maintain their export competitiveness during the period of crisis. The latest example is Japan. Japanese yen has depreciated by more than 20 per cent since September 2012. It sparked concerns that other countries would follow Japan to devalue their currencies to maintain international competitiveness[3]. But the Japanese authority argued that the sharp depreciation of yen is a market correction of overvalued yen over the past few years. The question arising from this debate is what the "appropriate" exchange rate of yen should be.

China is another example. Along with China's impressive performance in economic growth, Chinese currency, renminbi (also called yuan, henceforth, the RMB) exchange rate policy and the level of RMB exchange rates attracted intensive debates. China adopted managed floating exchange rate regime which indeed is to peg RMB to a single currency (the US dollar) or a currency basket[4]. Such exchange rate peg regime implies that the RMB's exchange rate needs to be "manipulated" so as to control excessive fluctuation of exchange rate. Not only China, but many economies do the similar thing on their currencies to different extents. Given China's economic size and trade share in the global economy, RMB exchange rates and the degree of its misalignment need to be carefully studied. More recently, it is widely believed that China's exchange rate policy significantly contributed to the global imbalance which might have led to 2007-2008 global financial crisis. Since July 2005, the RMB has appreciated by about 24 per cent in nominal term and 29 per cent in real term by the end of 2012. In addition, China's ratio of currency account surplus to GDP dropped considerably to 2.6 per cent in 2012 from 10.1 per cent in 2007. Chinese authority argued that the RMB is approaching to its equilibrium level and the RMB is no longer significantly undervalued. Naturally, we want to know if RMB exchange rate is approaching to an appropriate level and how the RMB

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within horizontal bands, Crawling peg, Crawling band, Managed floating with no pre-determined path for the exchange rate and Independently floating.

[2] Brazilian Finance Minister initiatively warned "Currency War" by saying that "we are in the midst of an international currency war" and "this threatens us because it takes away our competitiveness" in September 2010 when the global financial crisis was spreading across the world.

[3] Some policymakers like Governors of the Deutsche Bundesbank and Central Bank of Russian Federation expressed concerns on Bank of Japan's intervention in the yen's value.

[4] Recent studies illustrate that the RMB is still heavily pegging to the US dollar. But the dollar's weight in RMB basket steadily declined. Some currencies received increasing weight in some periods such as Malaysian ringgit, but not significantly (see Frankel and Wei 2007).

is misaligned.

There are many discussions on the RMB exchange rate issues. Among them, estimation of the RMB's "equilibrium" exchange rate is one of the fundamental questions. This research attempts to find if the RMB is undervalued or overvalued. If so, how much is the RMB misaligned from its equilibrium exchange rate. It employs the Clark and Macdonald (1998)'s the Behavioral Equilibrium Exchange Rate (BEER) approach to assess the degree of RMB misalignment from its equilibrium exchange rate which is determined by economic fundamentals. In contrast to previous empirical studies which used yearly or quarterly data, this study applies monthly data to find more detailed information about the dynamics of RMB misalignment over the period. In addition, we add more economic fundamentals which could explain the behaviors of RMB exchange rate into the BEER model as explanatory variables.

The remainder of this paper is organized as follows. Section Two is literature review. And it briefly reviews recent developments of RMB exchange rate and explains what equilibrium exchange rate means in section Three. This is followed by section Four in which the data and analytical framework are explained. In section Five, the findings are presented and analyzed. Section Six concludes the paper.

II. Literature Review

RMB equilibrium exchange rates and RMB misalignment have been intensively studied by applying various methodologies. Empirical results by using the BEER approach from Zhang (2001) indicate that there was a dramatic fluctuation of RMB misalignment from 1955 to 2000. He also finds the RMB was substantially overvalued before the 1980s. Bosworth (2004) estimates the RMB's equilibrium level based on three measurement approaches: purchasing power parity (PPP), macroeconomic balance, and accumulation of the foreign reserves in a fixed exchange regime. He finds the evidence of RMB undervaluation in PPP-based approach, while little or no RMB undervaluation by using other approaches. In addition, he argues that it is the large foreign capital inflows, rather than current account surplus, that caused the problem of RMB misalignment. Shi and Yu (2005) study the RMB's equilibrium exchange rates covering the period 1991-2004 by employing the BEER approach. They find the RMB deviated from its equilibrium level since the 1990s. More precisely, the RMB was undervalued from the second quarter of

1992 to the fourth quarter of 1994 while overvalued from the first quarter of 1995 to the second quarter of 1999. Based on the BEER model, Funke and Rahn (2005) find that since the mid-1996 the RMB had been undervalued by 11-15 per cent during the period of 1997-2002. Chen (2007) applies the BEER model to estimate the RMB's equilibrium exchange rates during the period of 1994 to 2006 by using quarterly data. He finds that the RMB was undervalued during the most of period, but has been approaching to its equilibrium exchange rate. Coudert and Couharde (2007)'s findings from the FEER approach illustrate that the RMB's real exchange rate was undervalued from 23 to 46 per cent during the period of 2002-2005. Wang and Hui (2007), by applying the BEER approach, argue that the RMB was not continuously undervalued but fluctuated around its equilibrium level within a narrow band from 3 per cent of overvaluation to 5 per cent of undervaluation during the period 1980-2005.

More recently, Li (2009) finds that the RMB's real exchange rates misaligned with its equilibrium exchange rates by -13.98 per cent (undervalued) to 16.66 per cent (overvalued) during the period of 1980-2007 by using the equilibrium real exchange rate (ERER) approach. By applying the ERER approach, Lin and Wang (2009) find the evidence of RMB overvaluation by 3-7 per cent from 2003 to 2007. The paper of Subramanian (2010) finds the RMB was undervalued by about 30 per cent in 2010 by applying a new PPP-based approach. Takagi and Shi (2010), by employing the Markov switching approach, finds that quarterly RMB exchange rates fluctuated between overvaluation and undervaluation during the period of 1992-2009. Meanwhile the period of RMB overvaluation overweighed the period of RMB undervaluation. By using the FEER model, Cline (2008), Cline and Williamson (2009, 2010, 2011, 2012) estimate the exchange rate misalignment for about 30 countries. They find an equilibrium exchange rate of the RMB against the US dollar should be 5.50 RMB per unit of the US dollar in 2010. That means that the RMB was undervalued by 21.55 per cent in this year, while the magnitudes of RMB undervaluation was 23.73 per cent in 2008 and 33.92 per cent in 2009. However, their latest research shows that RMB was undervalued in real effective term by 16 per cent in 2011 and 3 per cent in 2012 respectively. Their results imply that misalignment of the RMB shrank considerably from 2008 to 2012.

III. Background of RMB Exchange Rate and Equilibrium Exchange Rate

1. Recent development of RMB exchange rate

Two economic indicators were frequently cited by economists and politicians to assess the level of RMB exchange rate: current account surplus and foreign exchange reserves. China's ratio of current account surplus to GDP sharply surged since 1993, although it declined to around 2 per cent from 1997 to 2001 mainly because of Asian Financial Crisis. It then increased up to 10 per cent by the end of 2007 (see Figure 1). The ratio of current account surplus to GDP of China dropped dramatically again since 2008 when the global financial crisis struck. At the same time, from Figure 1, we can see that China's foreign exchange reserves grew considerably in the last two decades. China's long-lasting current account surplus and persistently increasing foreign exchange reserves may suggest that the RMB is misaligned. The recent drastic change of current account implies that empirical study on RMB misalignment by using latest data is needed.

Figure 1. China's ratio of current account surplus to GDP and foreign exchange reserves, 1978-2012
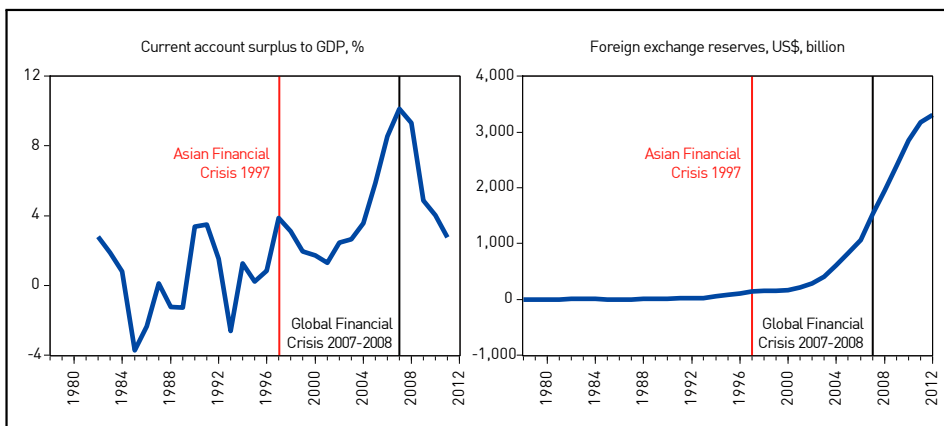

Source: WDI of World Bank and National Bureau of Statistics of China (NBSC).

Another phenomenon which may imply that the RMB deviated from its equilibrium level is China's increasing capital inflows which partly are in the formation of foreign direct investment (FDI) in the last several years. China

has been the largest FDI recipient country for decades (see Figure 2). The FDI took critical role in China's economic development by promoting technology progress and improving productivity. More recently, due to expectation of RMB appreciation, some speculative capital flowed into China in the formation of FDI because China's capital account has not been fully liberalized. Most of capital inflows in foreign exchange are required to convert into the RMB under the rules from China's State Administration of Foreign Exchange (SAFE). The RMB liquidity injected into financial system by the People's Bank of China (hereafter, the PBoC) is called the funds outstanding for foreign exchange. The amount of funds outstanding for foreign exchange in the PBoC's balance sheet has increased considerably since 1994. To avoid high inflation, the PBoC issued central bank bills to sterilize such RMB liquidity caused by converting foreign capital inflows into the RMB. Although the PBoC applied various policy tools such as issuing central bank bills to avoid high inflation, recent literatures release that the PBoC could not effectively and timely sterilize such extra liquidity. More capital inflows such as FDI or speculative capital in FDI formation mean that more RMB liquidity was injected into financial system, thereby increasing pressure of high inflation and RMB appreciation. Thus increasing amount of FDI inflows into China may have effect on RMB misalignment. We will include China's FDI inflows as one of economic fundamentals into the BEER model to measure RMB misalignment.

Figure 2. China's FDI inflows, 1982-2011
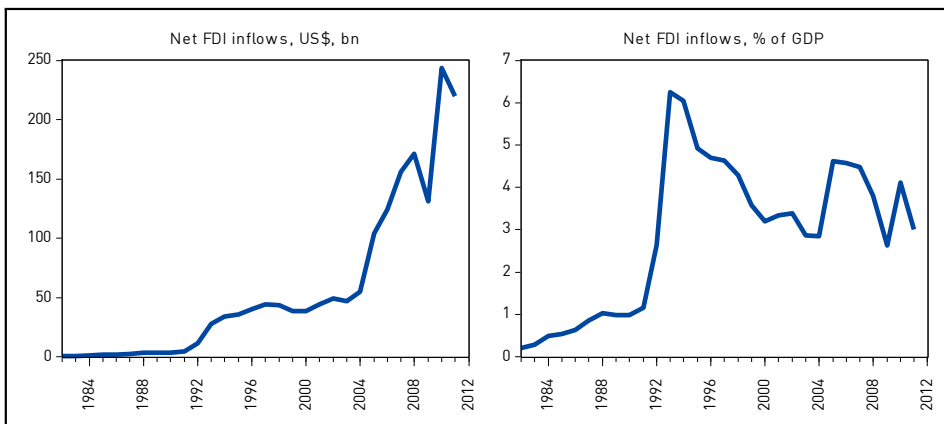
Source: World Bank database.

Since July 2005 when the new exchange rate policy was announced by the PBoC[5], it is notable that RMB nominal exchange rate has appreciated by 23.79 percent until the end of 2012 (see Figure 3), which is at about 3-4 per cent of annual rate. In the meanwhile, the REER of the RMB also increased substantially by 29 per cent by the end of 2012, although it dropped in 2009 during the period of crisis. RMB appreciation in nominal and real terms suggests that the RMB may be approaching to its equilibrium level: RMB misalignment is declining, if the RMB was undervalued.

Figure 3. RMB nominal exchange rate and REER, 1994-2012
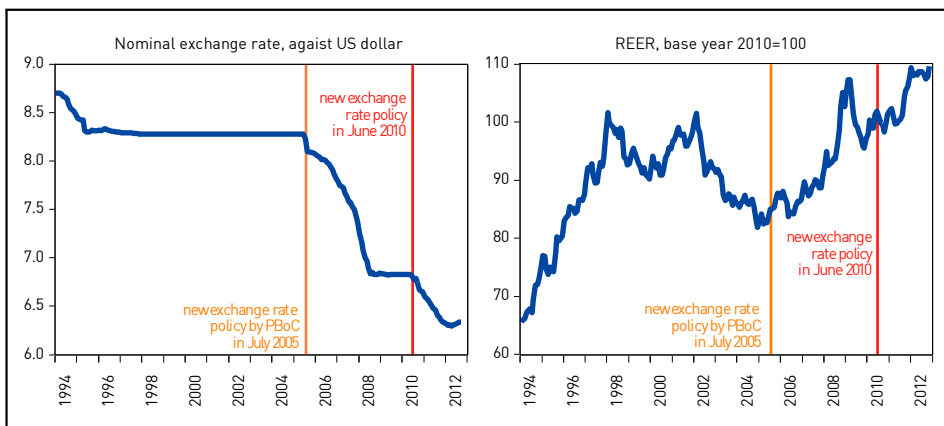
Source: The PBoC and BIS.

2. Equilibrium exchange rate

When judging one currency is undervalued or overvalued, it is assumed that there is an "appropriate" level of exchange rate for any currency, although some do not believe that such "equilibrium" situation exists (Dixit, 1990). In principle, we call this exchange rate as "equilibrium" exchange rate. *Robinson (1947) once wrote that there is an equilibrium rate corresponding to each rate of interest and level of effective demand, and a rate of exchange, can be turned into the equilibrium rate by altering the rate of the interest appropriately.[6]* Some argue

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[5] On July 21, 2005, People's Bank of China publicly announced that China would reform its exchange rate regime by moving to a managed floating exchange rate regime based on market supply and demand with reference to a basket of currencies. It means that the RMB would no longer be pegged to the US dollar and the RMB exchange rate regime would be more flexible.

[6] See Williamson (1994), "Estimating Equilibrium Exchange Rate", Institute for International Economics, p. 179.

that equilibrium exchange rate is the rate determined by all macroeconomic elements at any economic situation (Clark and Macdonald, 1998). On the other hand, according to Williamson (1994), the equilibrium exchange rate is the real exchange rate when one economy can achieve macroeconomic balance: internal and external balance simultaneously. It is a stable level of the exchange rate which is consistent with a desired macroeconomic outcome (Williamson, 1985). We should note here that the "equilibrium" situation is a dynamic rather than static process which means that the equilibrium exchange rate reflects the external and internal economic situation at the specific period. Assuming there exists a real equilibrium exchange rate for any currency, we could define the degree of deviation of the actual exchange rate from its equilibrium exchange rate as currency misalignment (Williamson, 1985). The magnitude of deviation from its equilibrium level illustrates how one currency is misaligned.

Nevertheless, measuring one currency's equilibrium exchange rate is still a challenging task for economists, although there are different economic models based on various economic theories and econometric skills, such as PPP-based approach, fundamental equilibrium exchange rate (FEER), behavioral equilibrium exchange rate (BEER) and so on. These approaches are applied in estimating RMB equilibrium exchange rate. The empirical results indicate that it is still difficult to judge how much the RMB is misaligned. Majority of empirical literatures by employing various methodologies conclude that the RMB was undervalued by a broad range from about 3 to 67 per cent since 2000 (Zhang 2001; Couder and Couharde 2005; Funke and Rahn 2005; Cline and William 2008, 2010, 2011 and 2012; Chen 2007 and Cheung *et al.* 2010). Empirical results vary when we use different economic methodologies. However, difficulty in estimating RMB misalignment does not necessarily mean that it is meaningless to estimate RMB equilibrium exchange rate. These methodologies complement each other to provide us a relatively robust assessment on RMB equilibrium exchange rate in the medium and long term. We will compare our results with previous findings.

IV. Data and Analytical Framework

1. Data

In this research, we attempt to employ the monthly data covering a long period to find more detailed evidences on RMB misalignment. However, monthly data for China and some countries are limited. For instance, Russia's monthly CPI

Table 1. China's top 20 trading partners in 2009 and 2010

Country (Region)	2009		Country (Region)	2010	
	Total (USD, bn)	Share to total trade		Total (USD, bn)	Share to total trade
United States	298.26	13.51	United States	385.64	12.96
Japan	228.78	10.36	Japan	296.57	9.97
Hong Kong, China	174.93	7.92	Hong Kong, China	227.71	7.66
Korea Rep.	156.21	7.08	Korea Pre.	206.83	6.95
Taiwan, China	106.22	4.81	Germany	142.45	4.79
Germany	105.64	4.79	Taiwan, China	112.88	3.79
Australia	60.13	2.72	Australia	86.93	2.92
Malaysia	51.97	2.35	Malaysia	74.19	2.49
Singapore	47.86	2.17	Brazil	62.50	2.10
India	43.38	1.97	India	61.74	2.08
Brazil	42.40	1.92	Singapore	56.19	1.89
Netherlands	41.81	1.89	Netherlands	55.40	1.86
United Kingdom	39.16	1.77	Russia	52.96	1.78
Russia	38.75	1.76	Thailand	50.08	1.68
Thailand	38.19	1.73	United Kingdom	45.13	1.52
France	34.46	1.56	Italy	44.97	1.51
Saudi Arabia	32.55	1.47	France	44.87	1.51
Italy	31.25	1.42	Indonesia	37.00	1.24
Canada	29.73	1.35	Canada	30.09	1.01
Indonesia	28.39	1.29	Vietnam	29.33	0.99
Sub total	1,630.06	73.84	Sub total	2,103.45	70.72
Total	2,207.53	100.00	Total	2,974.47	100.00

Source: Author's summery.

data is available from 1992, while Vietnam's monthly CPI data is available only from 1995. Furthermore, China started to report PPI data since September 1996 and monthly FDI data from 1997. Therefore the longest period we could cover is from January 1997 to December 2012. Majority of data is from CEIC, International Monetary Fund (IMF), World Bank's WDI database and National Bureau of Statistics of China (see Appendix 1).

In order to measure RMB equilibrium exchange rates, we need to calculate China's real effective exchange rates and other trade weighted explanatory variables. We use the bilateral trade share of China's top 20 trading partners in China's total trade with these 20 trading partners in 2010 as the trade weight of each trading partner with China. From Table 1, we can see that the US is China's largest trading partner which accounts for 18.33 per cent China's total trade, followed by Japan, Hong Kong SAR and South Korea in 2010. Vietnam is the smallest trading partner among China's top 20 trade partners, which accounts for 1.39 per cent of China's total trade in 2010. By comparing with China's main trading partners in 2009, there is little change in composition of China's main trading partners. It is also notable that China's trade with these 20 trading partners accounts for more than 70 per cent of China's total trade in 2010. Therefore our sample size is sufficient enough to include China's main trading partners.

2. Methodology

Clark and MacDonald (1998) firstly developed the behavioral equilibrium exchange rate (BEER) approach and used it to estimate equilibrium exchange rates of German mark, Japanese yen and the US dollar. Unlike the FEER approach which focuses on internal and external balance, the BEER approach interprets the behaviors of real exchange rate by a set of economic fundamentals. In other words, the behaviors of a set of economic fundaments determine the equilibrium exchange rate. In essence, any movement of one country's real exchange rate, to some extent, reflects the fluctuation of its economic fundamentals, such as interest rate, current account, terms of trade, foreign reserves and so on. The misalignment of exchange rate is the deviation of the actual real exchange rate from the BEER. According to Clark and MacDonald (1998), it can be described by a reduced-form equation:

$$q_t = \beta' Z_t \tag{1}$$

where q_t is the BEER, Z_t denotes a vector of economic fundamentals and β is a vector of coefficients.

Actual real effective exchange rate is composed of the BEER, transitory factor and disturbance term as below:

$$q'_t = \beta' Z_t + \tau' T_t + \varepsilon_t \tag{2}$$

where q'_t is actual real effective exchange rate, Z_t denotes a vector of economic fundamentals, T_t is a vector of transitory factor effecting the real exchange rate in the short term, and β and τ are the vectors of coefficients.

So current misalignment is the deviation of the actual exchange rate from its equilibrium real exchange rate:

$$q'_t - q_t = \tau' T_t + \varepsilon_t \tag{3}$$

Meanwhile, the long-run equilibrium real exchange rate is:

$$\overline{q}_t = \beta' \overline{Z}_t \tag{4}$$

where $\overline{q}_t$ is the long-run equilibrium exchange rate and $\overline{Z}_t$ is the vector of long-run economic fundamentals.

So total misalignment is deviation of actual real exchange rate from its long-run equilibrium exchange rate:

$$q'_t - \overline{q}_t = \tau' T_t + \varepsilon_t + \beta'(Z_t - \overline{Z}_t) \tag{5}$$

From equitation (5), we see that the total misalignment is composed of transitory factors, disturbance term and effect of deviation of economic fundamentals from their long-run values.

When employing the BEER approach to measure one currency's equilibrium exchange rate, one of the most important things is to judge which economic fundamental determines the behavior of real exchange rate over a period. Accuracy and rationality of results by using the BEER approach much depend on an appropriate set of economic fundamentals, especially for transitional economies, like China. Clark and MacDonald (1998) apply three economic fundamentals, including terms of trade, relative price of non-traded to traded goods and net foreign assets, to estimate equilibrium exchange rates for German mark, Japanese yen and the US dollar. In Zhang (2001)'s study, the economic fundamentals include gross fixed capital formation, government consumption (fiscal policy), growth rate of export and ratio of sum of foreign trade to GDP

(openness). Funke and Rahn (2005) apply the same methodology to assess "how undervalued is Chinese RMB". Economic fundamentals in their research are relative price of non-tradable to tradable goods and net foreign assets. Iossifov and Loukoianova (2007) estimate Ghana's equilibrium exchange rate by employing real GDP growth, real interest rate differential and real world prices of Ghana's main export commodities as economic fundamentals. Chen (2007) chooses relative price of non-tradable to tradable goods, net foreign assets, terms of trade and degree of openness to assess RMB misalignment. Wang *et al.* (2007) include more economic fundamentals as explanatory variables in the BEER model in assessing RMB equilibrium exchange rate. These variables are money supply, foreign reserves, terms of trade and relative price of non-tradable to tradable goods.

3. Econometric theory

In multiple time series analysis, vector autoregression (VAR) model, a generalized univariate autoregression (AR) model, is widely used in multivariate data analysis. An unrestricted VAR can be presented as:

$$x_t = \varphi_1 x_{t-i} + \varphi_2 x_{t-2} + \cdots + \varphi_p x_{t-p} + \varepsilon_t \tag{6}$$

i.e.
$$x_t = \sum_{i=1}^{p} \varphi_i x_{t-i} + \varepsilon_t \tag{7}$$

where x_t is a vector of variables (n×1), ε_t is a vector of white noise disturbance term with $E(\varepsilon)=0$, φ_i is a coefficient matrix for $i=1,...,p$, p is the order of autoregression. According to Engle and Granger (1987), x_t is a set of variables that may be stationary [*I(0)*] or non-stationary [*I(1)*]. It can be tested by using Augmented Dickey-Fuller (ADF) test. Johansen (1991) initially developed two likelihood ratio tests of cointegration which are trace statistic and maximum eigenvalue statistic. Compared with Engle-Granger test, Johansen test allows testing not only cointegration relations among more than two time series variables, but also the number of cointegrating relationships.

It is likely to find variables are nonstationary and there exist cointegrating relationships among variables. We use vector error correction model (VECM) in a VAR framework to find long-term relationship and short-term impact among variables. The VECM can be expressed as follow:

$$\Delta x_t = \prod x_{t-1} + \varphi_1^* \Delta x_{t-1} + \cdots + \varphi_{p-1}^* \Delta x_{t-p-1} + \varepsilon_t \tag{8}$$

i.e. $$\Delta x_t = \prod x_{t-1} + \sum_{i=1}^{p-1} \varphi_i^* \Delta x_{t-i} + \varepsilon_t \tag{9}$$

where φ* are functions of φ and Π is a matrix (n×n), that is:

$$\varphi_i^* = -\sum_{j=i+1}^{p} \varphi_j \qquad i=1,..., \ p\text{-}1 \tag{10}$$

$$\prod = -\sum_{i=1}^{p} \prod - I \tag{11}$$

where I is identity matrix.

4. The BEER model

The BEER model establishes a behavioral link between the real exchange rate and relevant economic fundamentals by applying econometric skills. As we mentioned earlier, selection of a set of economic fundamentals which play roles in determining equilibrium exchange rate is crucial in estimating RMB equilibrium exchange rate and RMB misalignment. In this study, we choose five economic fundamentals to as below:

BEER = F (BSE, ToT, OPENNESS, FR, FDI)

where:

BSE is Balassa-Samuelson Effect
    (Relative price of non-tradable to tradable goods)   (+)
ToT is terms of trade (ratio of export price to import price)   (+/-)
OPENNESS is the ratio of foreign trade to GDP   (+/-)
FR is the ratio of foreign reserves to GDP   (+)
FDI is the ratio of foreign directive investment to GDP   (+)

We follow Chen (2007) to calculate above variables. The calculation and expected sign of each variable are explained as follow:

1) The REER

The real effective exchange rate (REER) is the exchange rate weighted by trade share of home country to its trading partners with reference to relative prices (inflation). This trade weighted index is an economic indicator to compare international competitiveness between countries. Several institutions such as IMF, World Bank, Bank for International settlement (BIS) and so on, publish their REER indices. For example, the BIS reports the REER index which is calculated as geometric weighted averages of bilateral exchange rates adjusted by relative consumer prices for total 61 economies. In this research, we calculate our own REER index with reference to selected 20 economies which are China's main trading partners. The reason of calculating own REER index rather than using indices from other institutions is that we need to keep the same weight with other trade weighted variables. Increase in the value of REER represents real appreciation of the currency, while decrease of REER indicates real depreciation. The REER can be defined as:

$$REER = \prod_{i-1}^{N=20} [\frac{S^{PRC} \cdot CPI^{PRC}}{S^i \cdot CPI^i}]^{W^i} \qquad (12)$$

where S^{PRC} (S^i) is the nominal exchange rate of the RMB (nominal exchange rate of the currency of trade partner i). Both are bilateral exchange rates in the US dollar. (measured as US dollar price of one unit of other currencies). CPI^{PRC} (CPI^i) is the consumer price index of China (consumer price index of trading partner i). W^i is the trade weight which is trade share with trading partner i in China's total trade with these trading partners.

Rewriting (12) by taking natural log for both sides, we have:

$$reer = \ln REER$$
$$= \sum_{i=1}^{N=20} W^i (\ln S^{PRC} + \ln CPI^{PRC} - \ln S^i - \ln CPI^i)$$
$$= \sum_{i=1}^{N=20} W^i (s^{PRC} + cpi^{PRC} - s^i - cpi^i) \qquad (13)$$

2) Terms of trade

Terms of trade (ToT) is the ratio of exports price index to import price index. The ToT reflects one country's international economic environment where the

higher *ToT* implies one country can earn more from what they export and pay less for what they import. An improved long-term *ToT* indicates that one country can purchase more goods through international trade, thereby increasing overall national welfare. There is positive relationship between the *ToT* and real exchange rate because the increase in export prices relative to import prices will improve country's current account balance, thereby pushing currency's value to increase. According to the definition, the *ToT* could be expressed as follow:

$$ToT = \frac{EX^{PRC} / IM^{PRC}}{\prod_{i=1}^{N=20}(EX^i / IM^i)^{W^i}} \tag{14}$$

where EX^{PRC} (IM^{PRC}) is the export price index of China (import price index of China). EX^i (IM^i) is the export price index of trading partner i (import price index of trading partner i). W^i is the same as above.

Rewriting (14) by taking natural log for both sides, we have:

$$\begin{aligned} tot &= \ln ToT \\ &= (\ln EX^{PRC} - \ln IM^{prc}) - \sum_{i=1}^{N=20} W^i (\ln EX^i - \ln IM^i) \\ &= (ex^{PRC} - im^{PRC}) - \sum_{i=1}^{N=20} W^i (ex^i - im^i) \end{aligned} \tag{15}$$

3) The Balassa-Samuelson effect (relative price of non-tradable to tradable goods)

The Balassa-Samuelson effect (Balassa, 1964 and Samuelson, 1964) signifies that differentials of productivity growth between tradable goods sector and non-tradable goods sector result in distortion of purchasing power parity (PPP). This attributes to the fact that productivity improves faster in tradable goods sector than that in non-tradable goods sector. Under a fully international competitive environment, prices in non-tradable goods sector will grow along with the price increase in tradable goods sector, although productivity in non-tradable goods sector does not grow at the same pace as that in tradable goods sector. However, total price index for total economy comprised the prices of tradable goods and non-tradable goods. Therefore, total price index increases more rapidly in the fast-growing economy than those in other economies. It implies that the real exchange rate needs to appreciate. Thus we expect a positive relationship between the Balassa-Samuelson effect and real exchange rates.

   We define the ratio of the domestic consumer price index (CPI) to the domestic producer (wholesale) price index (PPI) relative to the corresponding trade-weighted ratio of trading partners as a proxy to Balassa-Samuelson effect (*BSE*). It can be expressed as follow:

$$BSE = \frac{CPI^{PRC} / PPI^{PRC}}{\prod_{i=1}^{N=20}(CPI^{i} / PPI^{i})^{W^{i}}} \tag{16}$$

where CPI^{PRC} and PPI^{PRC} are China's consumer price index and producer price index, respectively. Correspondingly, CPI^{i} and PPI^{i} are the trading partner i's consumer and producer (wholesale) price index. W^{i} is the same as above.
   Rewriting (16) by taking natural log for both sides, we have:

$$
\begin{aligned}
bse &= \ln BSE \\
&= (\ln CPI^{PRC} - \ln PPI^{PRC}) - \sum_{i=1}^{N=20} W^{i}(\ln CPI^{i} - \ln PPI^{i}) \\
&= (cpi^{PRC} - ppi^{PRC}) - \sum_{i=1}^{N=20} W^{i}(cpi^{i} - ppi^{i})
\end{aligned}
\tag{17}
$$

4) Degree of openness

   Degree of openness significantly influences country's real exchange rate because the extent of openness has effect on prices and volume of country's imports and exports which are sensitive to exchange rate. Moreover, degree of openness captures the dynamics of current account balance which is influenced by the exchange rate to some extent. However, how dose the openness affect real exchange rate remains uncertain. For a catching-up economy, on the one hand, higher degree of openness stimulates importing more goods which may impair country's terms of trade. So there may be a negative relationship between openness and real exchange rate. On the other hand, higher openness may indicate better current account situation which results in currency appreciation. Therefore openness may have positive effect on real exchange rate. Conventional measurement of degree of openness is the ratio of total foreign trade to nominal GDP as below:

$$OPENNESS = (EX^{PRC} + IM^{PRC}) / GDP^{PRC} \tag{18}$$

where *OPENNESS* is degree of openness, EX^{PRC} (IM^{PRC}) is China's monthly value of exports (imports) and GDP^{PRC} is China's nominal GDP.

5) Foreign reserves

We also include the ratio of foreign reserves to nominal GDP as an economic fundamental into the BEER model to estimate the degree of RMB misalignment. The amount of foreign reserves reflects the situations of current account and financial account. In principle, the increase of current account surplus which is tightly related to the level of exchange rate would build up country's foreign reserves. Therefore the amount of foreign reserves as an economic fundamental takes role in determination of country's equilibrium exchange rate. It is particularly true for China. Figure 1 shows tremendous increase in China's foreign reserves during the period of 1980 to 2010. Accumulation of foreign reserves created by current account surplus requires currency appreciation to balance current account. Thus positive relationship between foreign reserves and real exchange rate is expected. We employ the ratio of China's foreign reserves to nominal GDP as follow:

$$FR = foreign\_reserves^{PRC} / GDP^{PRC} \qquad (19)$$

6) Foreign direct investment (FDI)

The FDI positively promotes China's exports during the process of China's rapid economic growth, thereby improving China's current account situation. Therefore it has effect on China's real exchange rate. More recently, FDI became a channel for foreign capital to flow into China when China remained its capital account tightly controlled. China's PBoC had to issue more central bank bills to sterilize such foreign capital inflows. It not only increased operation costs of central bank, also caused higher inflation. Thus we expect positive effect of FDI inflow on real exchange rate. It is expressed as follow:

$$FDI = FDI\_\inf low^{PRC} / GDP^{PRC} \qquad (20)$$

7) Trade weights of trading partners

Trade weight is the foreign trade share of each trading partner of China in China's total trade with these 20 trading partners. In this study, we calculate

the percentage of each of China's top 20 trading partners in China's total foreign trade in 2010 as the average trade weight of each trading partner. It includes almost all of China's main trading partners from 1997 to 2012 (See Table 1).

$$W^i = Trade^i / Totaltrade \qquad (21)$$

where W^i is trade weigh of China's trading partner i, $Trade^i$ is the amount of China's foreign trade with trading partner i and $Totaltrade$ is the amount of China's total foreign trade with these 20 trading partners.

V. Results Analysis

Figure 4 reports the dynamics of the RMB's REER and five economic fundamentals over the period. The REER of the RMB we calculated, fluctuated from 1995 to 1997, and then increased sharply in 1998. It dropped from 1999 to mid-2000 and recovered boldly by the end of 2001. Since 2002, it declined sharply until the end of 2004. From 2005, the RMB's REER remained relatively stable except 2008 and 2009 when global financial crisis struck the world economy. The fluctuation of REER of the RMB is very different from the movement of its nominal exchange rate. It reflects the fact that the RMB real exchange rate did not appreciate continuously as its nominal exchange rate did (see Figure 3). For the Balassa-Samuelson effect, in general, there is an upward trend, although it decreased in 1997 and 2008. It reflects the impact of Asian financial crisis 1997 and global financial crisis 2007-2008 on China's export industry. China's terms of trade deteriorated since 1997 mainly due to the fact that Asian Financial Crisis 1997 negatively impacted on China's exports. It recovered dramatically from 2002 until the end of 2008. Because of the global financial crisis which seriously struck China's exports, China's terms of trade dropped considerably again in 2008, although it recovered boldly since 2009. China's openness increased continuously except for 2008 and 2009 when growth rate of exports declined due to weak demand for China's export goods during the period of crisis. Also, China's foreign reserves started to be accumulated since 1997. We can see that the ratio of foreign reserves to GDP increased continuously, reaching the peak in 2010. It dropped steadily in 2011 and 2012. What's more, China's FDI inflows increased dramatically during the period we covered. In contrast, the ratio of FDI inflows to GDP did not grow but declined slightly over the period.

Figure 4. The RMB's REER and five economic fundamentals, 1995-2012
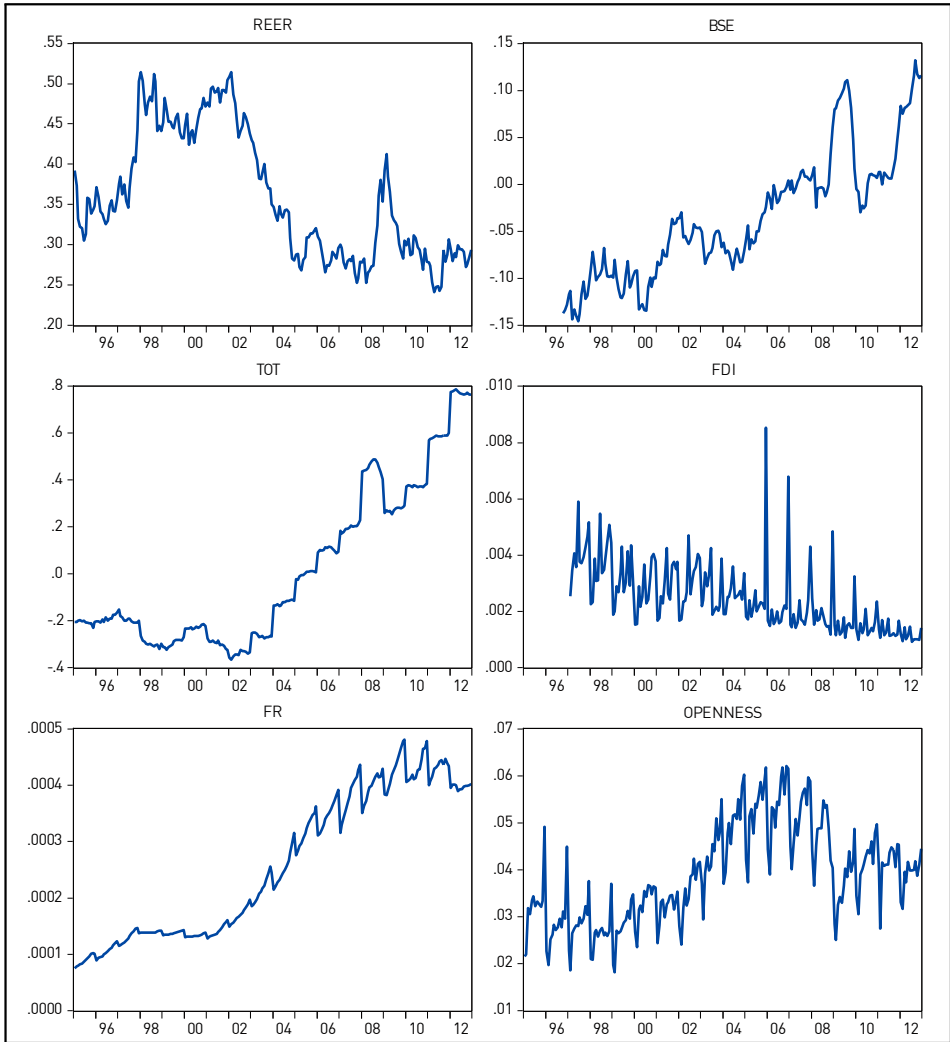
Source: Author's calculation.

Empirically, for vector auto regression (VAR) analysis, we need to test if all variables are stationary or not. Results of augmented Dickey-Fuller (ADF) test show that all variables in level are non-stationary and there is unit root *I(1)* in each variable, while variables in first difference are stationary *I(0)* (see Table 2).

Table 2. Unit root test by ADF test

Variable	ADF test	Critical value		ADF test	Critical value		I (1) or I (0)
		at 1%	at 5%		at 1%	at 5%	
		Levels			First difference		
reer	-1.4253	-3.4607	-2.8748	-12.8659	-3.4609	-2.8749	I (1)
bes	-0.7529	-3.4641	-2.8763	-12.3211	-3.4628	-2.8764	I (1)
tot	1.0048	-3.4607	-2.8748	-13.9500	-3.4609	-2.8749	I (1)
fr	-1.3436	-3.4626	-2.8756	-1.9418	-3.4626	-2.8756	I (1)
openness	-1.6945	-3.4627	-2.8757	-2.9450	-3.4627	-2.8757	I (I)
fdi	-1.3436	-3.4926	-2.8756	-1.9418	-3.4626	-2.5743	I (I)

Source: Author's calculation.

With all variables being *I(1)*, we adopted Johansen test to see if there are cointegration relationships among all variables. Johansen test provides two cointegration tests: the trace test, and the max-eigenvalue test. Table 3 shows that there are three cointegration relationships from the trace test and four cointegration relationships from the max-eigenvalue test.

Table 3. Johansen test for cointegration:

Number of obs.=184
Lags=6

Rank	Trace statistic		5% critical value	Max-eigenvalue		5% critical value
None	147.1377	*	95.7537	52.3363	*	40.0776
1	94.8014	*	69.8189	35.6286	*	33.8769
2	59.1728	*	47.8561	31.8789	*	27.5843
3	27.2939		29.7971	22.8078	*	21.1316
4	4.4861		15.4947	4.1129		14.2646
5	0.3731		3.8415	0.3731		3.8415

Source: Author's calculation.
Note: * significant at 5 per cent.

We then proceed to estimate VECM model. Table 4 presents the coefficient of each variable. Coefficients of *bse*, *tot, openness* and *fdi* are significant, while

the coefficient of *fr* is not significant. Equation (22) can be used to calculate the BEER of RMB.

Table 4. VECM results

Number of obs. =181
R-squared=0.8271

| beta	Coefficient		Std. Err.	z	P>|z|
reer	1.0				
bes	-1.1367	*	0.21872	-5.20	0.000
tot	0.3931	*	0.05787	6.79	0.000
fr	120.9681		188.73070	0.64	0.522
openness	6.7596	*	1.02930	6.57	0.000
fdi	41.3148	*	14.10879	2.93	0.003
constant	3.3053	*	.	.	.

Source: Author's calculation.

The long-run relationship between the BEER of RMB and China's economic fundamentals is:

$$BEER = -1.137 \times BES + 0.393 \times ToT + 41.315 \times FDI$$
$$+ 6.760 \times OPENNESS + 3.305 \tag{22}$$

All explanatory variables have expected signs except for the *BES*. As theory suggests, there should be positive relation between the Balassa-Samuelsson effect and real exchange rates. Negative signs of the *BES* may imply that Balassa-Samuelson effect did not significantly affect RMB equilibrium exchange rates as much as it does other economic fundamentals during the period covered. By using equation (22), we calculate the BEER of the RMB. According to Clark and Macdonald (1998), the long-run economic fundamentals can be obtained by using Hodrick-Prescott filter, therefore the RMB's long-run BEER also can be computed from equation (22). We then convert the RMB's actual REER, the BEER and the long-run BEER into indices (see Figure 5).

Figure 5. The RMB's actual REER, BEER and long-run BEER, based year=1997
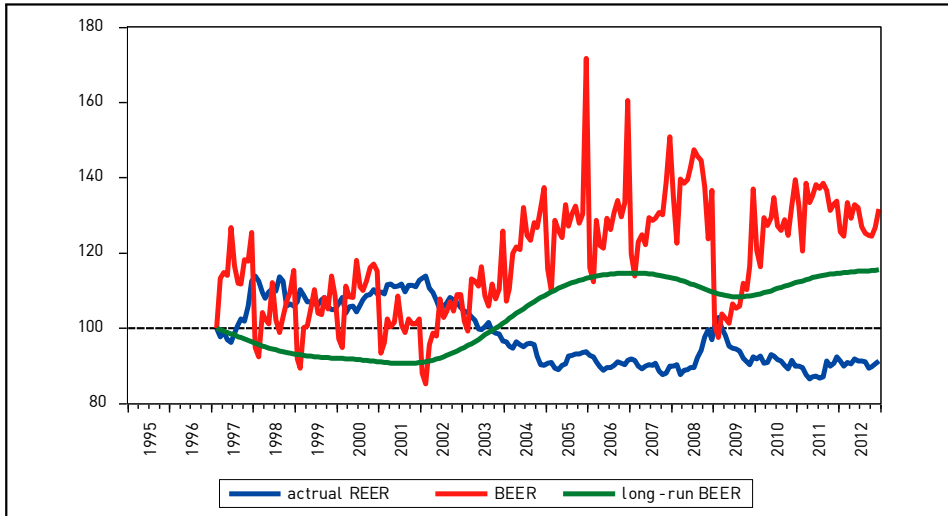
The RMB misalignment is the deviation of the RMB's actual REER from its equilibrium exchange rate, the BEER. So we have:

$$misalignment = (actual\_REER - BEER)/BEER \times 100\% \qquad (23)$$

Using equation (23), we calculate the RMB's current misalignment dividing the differential between the RMB's actual REER and BEER by the RMB's BEER. In the same way, the RMB's total misalignment can be computed by replacing the BEER with the long-run BEER. The RMB is overvalued when RMB misalignment is more than zero, while the RMB is undervalued when RMB misalignment is less than zero. Figure 6 illustrates the dynamics of the RMB's current and total misalignment over the period of 1997-2012.

Figure 6 provides us an explicit image that how the RMB was misaligned from its equilibrium level over the period of 1997-2012. Before 2002, the RMB was overvalued by 10 to 20 per cent. It is mainly because that China's terms of trade deteriorated with the Asian Financial Crisis in 1997 when China kept RMB exchange rate stable while other East Asian currencies were sharply devaluated. It caused China's export goods more expensive than those of its competitors. Additionally China's foreign reserves and FDI inflows did not increase significantly during the same period (see Figure 4). From 2003 to 2005,

Figure 6. The RMB's current misalignment and total misalignment, 1997-2012
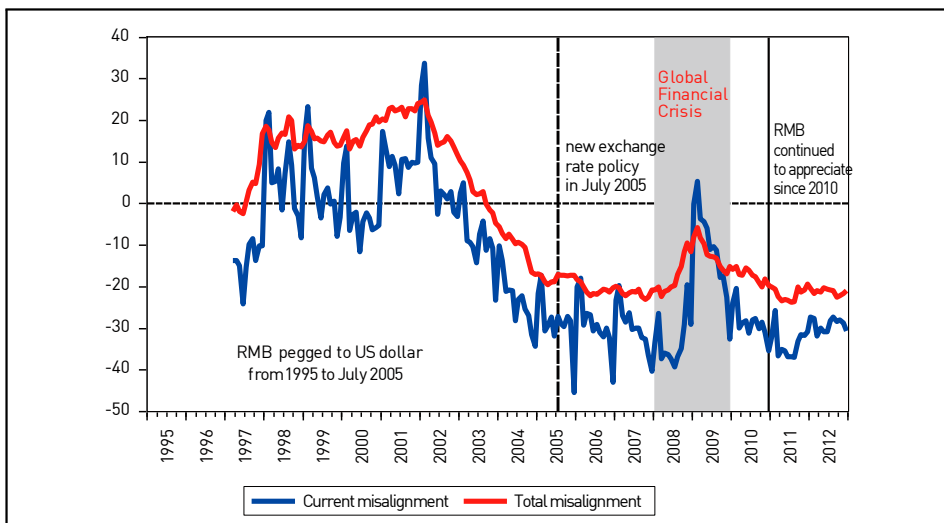
Source: Author's calculation.

the RMB gradually shifted from overvaluation to undervaluation. During this period, China's terms of trade was improved with increased current account surplus and substantially accumulated foreign reserves, while the RMB was tightly pegged to the US dollar. Thus we see that the RMB moved from overvaluation to undervaluation at about 20 per cent by the mid-2005. After the announcement of new exchange rate policy in July 2005, RMB nominal exchange rates started to be gradually revaluated. Figure 6 shows that RMB misalignment maintained relatively stable at about 20 per cent from mid-2005 to the end of 2006. Also, we find that the RMB showed the trend of approaching to its equilibrium level and RMB misalignment narrowed since 2007. The RMB's total misalignment declined to about 10 per cent by the end of 2008. However, the global financial crisis disrupted the trend of the RMB approaching to its equilibrium level. Since the second half year of 2008, the RMB re-pegged to the US dollar until the mid-2010 (see Figure 3). Meanwhile, the currencies of China's major trading partners depreciated during the same period. We find that the RMB's total misalignment dramatically increased from about 8 per cent in the beginning of 2009 to 25 per cent in the end of 2010. More recently, since 2011, China also suffered relatively high inflation compared to other countries. Meanwhile, the RMB continued to appreciate in nominal and real terms (see Figure 3). At the same time, China's ratio of current account surplus to GDP shrank sharply from

10.1 per cent in 2007 to 2.6 per cent in 2012. Such significant changes induced declining total misalignment of RMB since 2012, although it is not significant.

Our result is consistent with the findings in previous studies in term of the trend of RMB misalignment. However, it is worthwhile to note that it is still difficult to make consensus on what equilibrium exchange rate of the RMB should be. As Cheung, Chinn and Fujii (2010) point out, it is unlikely to reach an agreement on RMB equilibrium exchange rates and RMB misalignment due to theoretical and empirical difficulties. As mentioned earlier, the conclusions on degree of RMB misalignment differ with various economic methodologies. Our findings provide a new estimation result of RMB misalignment, although it should be interpreted cautiously.

VI. Conclusions

It is widely believed that the RMB was undervalued over the last decade. Recently, the RMB significantly appreciated in nominal and real terms. Debate on RMB misalignment remained unclear, although Chinese authority argued that the RMB is approaching to its equilibrium level. In this paper, by applying the BEER approach, it is estimated how the RMB is misaligned from its equilibrium exchange rate during the period of January 1997 to December 2012. We find that the RMB was overvalued by 10-20 per cent from 1997 to 2002. Since 2003, the RMB gradually shifted from overvaluation to undervaluation. Until mid-2005, the RMB was undervalued by around 20 per cent. From 2007, the RMB started to gradually approach to its equilibrium level. By the end of 2008, the RMB was undervalued by 10 per cent. However, the global financial crisis disrupted this trend when the RMB re-pegged to the US dollar, and many emerging economies' currencies were significantly devalued during the period of crisis. The RMB's total misalignment increased to around 25 per cent in the mid-2011. Since June 2010 when Chinese monetary authorities reaffirmed that China would further reform the RMB exchange rate regime and enhance the RMB exchange rate flexibility, the RMB continued to appreciate. In the meanwhile, the ratio of current account surplus to GDP of China shrank considerably. These macroeconomic changes induced total misalignment of the RMB's slight decline in 2012, but not significantly. Our findings prove that there is a trend of RMB approaching to its equilibrium exchange rate since China launched exchange rate reform in July 2005, although this trend was interrupted by the global financial crisis.

Appendix 1: Data Description and Sources

To differ from previous studies on RMB equilibrium exchange rate by applying the BEER model, monthly data is used to find more detailed information on RMB misalignment. Period covered in this paper is from 1997 to 2012 given data availability. Majority of data is from CEIC[7], International Monetary Fund (IMF) and National Bureau of Statistics of China. More detailed information about data as below:

Trade weights of China's 20 trading partners:
China's foreign trade data by trading partner is from the National Bureau of Statistics of China. This study compared China's top 20 trading partners in 2005-2010 and found little change of the composition of China's top 20 trading partners during this period. We used bilateral trade share of China's top 20 trading partners in China's total trade with these 20 trading partners in 2010 as trade weight of each trading partner because we pay particular attention on RMB misalignment in recent years.

REER:
Monthly data of CPI and bilateral nominal exchange rates of each country against the US dollar are from CEIC. However, for Australia, only quarterly CPI data are reported so that quarterly CPI, instead of monthly CPI, are used for the country. Also, while base year of CPI index varies among countries, it is converted for all countries to have the base year of 2005.

Terms of Trade (ToT):
Majority of monthly data of import and export price index are from CEIC and International Financial Statistics (IFS) of IMF. China, Russia and Vietnam do not report their import and export price index, therefore, for these three countries, yearly import and export volume index and import and export value index from WDI of World Bank are used.

Balassa-Samuelson Effect (BSE):
Monthly data of CPI and PPI of each country is from CEIC. CPI data is

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[7] CEIC is the database provides economic and financial data from emerging and developed economies. See http://www.ceicdata.com/about_ceic.html.

also used in computing the REER. However, PPI data is limited and not enough to cover our period of 1997 to 2012. For the countries that do not report monthly PPI or cover long enough periods of monthly series data, like Australia, Hong Kong and Vietnam, quarterly or yearly PPI data are used instead.

Degree of openness (OPENNESS):
China's monthly data of import and export as well as yearly GDP are from CEIC.

Foreign reserves (FR):
China's monthly data of foreign reserves is from CEIC.

Foreign direct investment (FDI):
China's monthly data of FDI is from CEIC. However, it is FDI stock data rather than flow data. Given that, monthly FDI flow data is computed.

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About the Author

Yuming Cui is a Ph.D. candidate at Graduate School of Asia-Pacific Studies, Waseda University, Japan. He has worked as a Research Associate at Asian Development Bank Institute (ADBI), Japan and Researcher at Centro Europa Ricerche (CER), Italy. His areas of research include financial economics, East Asian Economics and Chinese economy. His recent publications include: "New Evidence of Asian Economic Integration: Trilateral FTA between China, Japan and Korea"; and "The Internationalization of the RMB: Where does the RMB Currently Stand in the Process of Internationalization" (forthcoming). He is currently working on his doctoral thesis on China's exchange rate regime and the RMB internationalization.