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Beyond cheap talks: Assessing the undervaluation of the Chinese currency between 1994 and 2007

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Abstract. Relying on new cointegration framework with structural breaks in the deterministic trend, this article employs the behavioral equilibrium exchange rate (BEER) approach to estimate the equilibrium real exchange rate of Renminbi (RMB) and exchange rate misalignment in China from 1994Q1 to 2007Q4. The main findings of the article are that RMB was overvalued during the Asian financial crisis and during the period of 2001-2002. It was undervalued to a mild extent only during recent period from 2003 to 2005, except at the beginning of the sample; furthermore, slight overvaluations have appeared after the reform of exchange rate regime in 2005. Interpretations are given to shed some light on these movements.

JEL Classification: F31; F32; F41; C32.
Keywords: Behavioral Equilibrium Exchange Rate; Renminbi; Misalignment; Cointegration; Structural Break.

Résumé. Recourant à l'approche comportementale du taux de change d'équilibre (BEER), cet article estime le taux de change réel d'équilibre du Renminbi (RMB) et le mésalignement de change correspondant en Chine, pour la période allant du 1er trimestre 1994 au 4ème trimestre 2007. Au niveau méthodologique, l'analyse s'appuie sur la cointégration avec ruptures structurelles, introduite par Johansen *et al.* (2000). Le principal résultat est que le RMB était surévalué pendant la crise financière asiatique et durant les années 2001-2002. Dans une certaine mesure, il n'était sous-évalué que sur la période récente, 2003-2005, sauf au début de notre échantillon ; de plus, de légères surévaluations ont été constatées après la mise en place du nouveau régime de change en 2005. Diverses explications sont suggérées afin d'expliquer ces variations.

Classification *JEL* : F31 ; F32 ; F41 ; C32.
Mots-clefs :Taux de change d'équilibre comportemental ; Renminbi ; mésalignement ; cointégration ; rupture structurelle.

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1. Introduction

China's continuous large trade surpluses (especially with the United States) and rapid accumulation of foreign exchange reserves make it plausible to consider that the strong growth is principally due to the undervaluation of the Chinese currency, Renminbi (RMB) and the rigid exchange rate regime.[2] Furthermore, after the reform of China's exchange rate regime in 2005, the continual rise of the value of RMB against the U.S. dollar (USD) in the first six months of 2008 and the rise to the strongest (6.7800 per dollar) since the peg to the dollar was scrapped in 2005 seem to have convinced the public that the RMB was really undervaluated.[3] [4] However, to evaluate whether one currency deviates from its appropriate level (and to conclude the undervaluation or overvaluation) or not, we should resort to an adequate benchmark rate, the equilibrium exchange rate, instead of relying only on what happened. Does such behavior represent movements of underlying equilibrium, implying the currencies are adequately valued, or do these movements represent misalignments? In this article, we employ the behavioral equilibrium exchange rate (BEER) approach to estimate the RMB equilibrium exchange rate and the relevant misalignments, using quarterly data from the first quarter of 1994 to the last quarter of 2007, and to shed some light on their evolutions.[5]

Among the methods employed to estimate the equilibrium exchange rate, the Purchasing Power Parity (PPP) approach always comes as the first reference because of its simplicity.[6] Two other main approaches have been developed to estimate the real equilibrium exchange rate and misalignment of a currency. One is the fundamental equilibrium exchange rate (FEER) approach, proposed by Williamson (1985) and applied by many authors to both developed (see Williamson, 1985; Driver and Wren-Lewis, 1998) and developing countries (Jeong and Mazier, 2003; Coudert and Couharde, 2005). The other is the Behavioral Equilibrium Exchange Rate (BEER) approach of Clark and MacDonald (1998).[7] It involves the direct econometric analysis of the relationship between the behavior of actual exchange rate and its relevant economic fundamentals.[8]

We choose BEER approach for estimating RMB's real equilibrium exchange rate for three reasons: first, this approach is more practical as it involves estimating a reduced-form equation. Thus it is largely applied to measure real equilibrium exchange rate and misalignments

2. The Chinese currency is generally known as the Renminbi (literally, "people's money"), sometimes used as "Yuan" which is the unit of account. In the rest of this article we use its abbreviation "RMB".

3. On July 21, 2005, China revalued the RMB by 2.1 percent to 1USD=8.11RMB, and announced that it would switch from dollar-peg to a basket-peg, and that it allows for more flexible floating of the currency.

4. The RMB has gained 6.0 percent against the dollar in the first six months of 2008, following the gain of 7 percent in 2007.

5. The misalignment was defined by Williamson (1985) as a persistent departure of the exchange rate from its long-run equilibrium level.

6. How to use this approach for estimation is discussed in Ohno (1990) and Rogoff (1996). Yi and Fan (1997) and Chou and Shih (1998) have used this approach to estimate the equilibrium exchange rate of the Chinese currency.

7. For a complete comparison of these two approaches and discussion of other alternative measures, see e.g., Clark and MacDonald (1998); MacDonald and Ricci (2007).

8. We will discuss this approach in detail in Section 3.

(e.g. Baffes *et al.*, 1999; Clostermann and Schnatz, 2000; Maeso-Fernandez *et al.*, 2002). Second, when studying the misalignment of exchange rate for developing countries, BEER is proved to be efficient and powerful for finding the long-run relation between the real exchange rate and its fundamental variables (Montiel, 1999), despite some data limitation (e.g., small sample, availability, and/or quality of data) or instability of the economic structure. Finally, in view of these two main advantages, this approach is widely used to estimate equilibrium exchange rate and undervaluation of RMB, which has stirred up an intense controversy since several years.[9]

This article differs from previous studies in several ways. Firstly, the estimation of a long-run relation between the BEER of RMB and its fundamentals is implemented within the framework of cointegration analysis with the presence of structural breaks in the deterministic trend (or constant) of Johansen *et al*. (2000), when real exchange rate and/or its fundamentals exhibit some visible structural changes. Therefore, this is the first article to use this more general framework to assess the equilibrium exchange rate of RMB.[10] Consequently, the calculation of equilibrium exchange rate and relevant misalignment take into account the impact of structural changes on the system, which prove more robust than some previous studies. Secondly, efficient unit root (UR) test (ERS and NG) and Break-considered test (LS) are employed to overcome the size distortion and low power that other traditional UR tests suffer from, even as taking into account the structural changes (with the LS test). These tests allow ensuring that the fundamentals entering into cointegrating vectors are integrated to the order of one without wrongly accepting the null hypothesis of unit root when it is stationary with structural breaks. Thirdly, under alternatives assumptions, BEERs are calculated and compared, which show the robustness of our results. Last but not least, without calculating a bilateral USD/RMB real exchange rate as Zhang (2001) and Coudert & Couharde (2005), our estimation is based on a multilateral Consumer Price Index (CPI)-based real effective exchange rate calculated with more precise trade weights.[11] We increase the number of trade partner countries involved in the calculation of effective exchange rate up to 13 countries. This allows to take into account the greater impact of partner countries on this rate and to raise the accuracy of the variables.[12] For each of these countries, a fixed weight (average of 1999 to 2001) is calculated and also used for other three weighted economic fundamentals that will be defined in subsection 4.2. Moreover, the quarterly data used cover the period from 1994Q1 to 2007Q4. The time period therefore began with a unified exchange rate regime established at that moment, and includes the period following the exchange rate regime reform of 2005.[13]

9. All articles cited in the next paragraph use the BEER approach for estimating RMB's equilibrium exchange rate.

10. The exchange rate of Euro against USD has been analyzed within this model by Goux (2005).

11. See e.g., Zhang (2002), Funke and Rahn (2005), Shi and Yu (2005) for CPI-based real effective exchange rate.

12. Whereas Funke and Rahn (2005) only take Japan, the U.S. and Euroland as China's main trading partners; Shi and Yu (2005) calculate the effective exchange rate weighted by seven trade partner countries.

13. Alternatively, the data before 1990 (Funke and Rahn, 2005) or annual data dating back even to 1950s (Zhang, 2001; Lin, 2002) are used to increase the sample size. In these circumstances, as the prices were controlled by Chinese government as a tool for planned economy before 1980 and not totally market-based in the beginning of 1990s, the credibility of their estimations is not sure.

This permits seeing what happened to RMB after this so-called "historic" reform. Accordingly, the article provides a guide for computing equilibrium exchange rates for other developing countries.

The results of this article show overvaluations of RMB during the Asian financial crisis and during the period of 2001-2002 (up to 28 percent), and undervaluations of mild extent (at most 8 percent) during the recent period of 2003-2005, except at the beginning of the sample. Furthermore, slight overvaluations (at most 6 percent) have appeared after the reform of exchange rate regime in 2005. Concerning the misalignments of RMB since 2003, our results are consistent with that of studies using single-country estimation of RMB.[14]

This article is organized as follows: In the next section, we present the background of exchange rate regimes and relevant policies in China during the considered period. In Section 3, the BEER approach and the cointegration framework of Johansen *et al.* are discussed. Section 4 involves the selection of variables, the definitions, and sources of data. Section 5 presents the results of estimation: following the univariate Unit Root and cointegrating analysis, the equilibrium exchange rate and misalignment are reported. Interpretations of their movements are given in Section 6. The final section concludes with some policy recommendations and suggestions for future research.

2. China's exchange rate regimes: A brief review

With the advent of the People's Republic of China, Chinese RMB was first inconvertible. However, since economic reform of 1978, Chinese policymakers have realized the importance of exchange rate as a tool for adjusting its economic relation with foreign countries. From 1981 to 1994, two dual systems of exchange rate have been successively implemented by the monetary authorities. Later, in January 1994, the dual exchange rate system was replaced by a system that unified the official exchange rate with the parallel "swap market" rate, resulting in the managed float exchange rate regime. The interbank foreign exchange market was officially opened on April 4, 1994 and the designated banks were to buy and sell foreign currencies to determine the exchange rate within the given benchmark range fixed by People's Bank of China (PBOC, China's central bank).[15] On December 1, 1996, China had formally accepted the obligations of Article VIII of the IMF's Articles of Agreement, making RMB convertible under current account. However, the bilateral exchange rate of RMB vis-à-vis USD remained very stable, even during the period of the Asian currency crisis. Thus, China's exchange rate regime at that time was considered as a peg *de facto* to the dollar. This situation did not change until 21 July, 2005, when the PBOC announced a revaluation of the currency and a reform of the exchange rate regime

14. The results show obvious difference when compared with those of panel estimation (see e.g., Bénassy-Quéré *et al.*, 2004, 2009a & b).

15. The China Foreign Exchange Trade System (CFETS) in Shanghai (an integrated electronic system for interbank foreign exchange trading) came into operation. Twenty-two cities were linked to this system by the end of 1994 (IMF, 1995, p.114).

after about a decade of strictly pegging the RMB to the USD at an exchange rate of 8.28. The revaluation placed the RMB at 8.11 against the dollar, an appreciation of 2.1 percent. Under this reform, the PBOC incorporated a "reference basket" of currencies when choosing its target for the RMB. The initial target of fluctuation was fixed in a range of 0.3 percent around the benchmark rate.

3. Methodology

3.1. The BEER approach

The BEER approach is used to estimate the equilibrium exchange rate of RMB. The main reason is that this method is well suited to developing countries for which large and complex models are often not feasible because of the quality and availability of data (Zhang, 2001). The following discussion about this approach is based on Clark and MacDonald (1998). An estimated reduced-form equation is used to explain the behavior of real effective exchange rate with its relevant economic fundamentals:

$$q_t = \beta' Z_t + \tau' T_t + \varepsilon_t \tag{1}$$

q_t = actual real effective exchange rate;
Z = a vector of economic fundamentals that are expected to have influence on the real exchange rate over the medium and long run;
T = a vector of transitory factors affecting the real exchange rate in the short run;
β, τ = vectors of reduced-form coefficients;
ε_t = random disturbance term.

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

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

$$q_t' = \beta' Z_t \tag{2}$$

Therefore, mis_cur_t is defined as the difference between the actual rate and the real exchange rate determined or adjusted by the current value of the economic fundamentals:

$$mis\_cur_t = q_t - q_t' = \tau' T_t + \varepsilon_t \tag{3}$$

However, as mentioned earlier, it is possible that the current value of the fundamentals deviates from their long run sustainable level; therefore, the total misalignment, mis_per_t, is defined as the difference between the actual real rate and the real rate determined by the long-run values of the economic fundamentals, which are denoted by $\bar{Z}_t$:

$$mis\_per_t = q_t - \beta' \bar{Z}_t \tag{4}$$

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

$$mis\_per_t = (q_t - q_t') + \beta'(Z_t - \bar{Z}_t) \tag{5}$$

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

$$mis\_per_t = \tau' T_t + \varepsilon_t + \beta'(Z_t - \bar{Z}_t) \tag{6}$$

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

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

Where *tnt* is the relative price of non-traded to traded goods, *NFA* is net foreign assets, *tot* is the terms of trade, *OPEN* is the degree of openness. It is then needed to estimate the following single equation:

$$BEER = (tnt, NFA, tot, OPEN) \tag{8}$$

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

3.2. Cointegrating framework

The basic econometric method used is the cointegrating model with piecewise linear trend and known break points proposed by Johansen *et al.* (2000), which itself is a slight generalization of the cointegrating method of Johansen (1988, 1995). The starting point is the basic *p*-dimensional vector autoregressive model with no break:

$$X_t = A_1 X_{t-1} + \ldots A_k X_{t-k} + At + \mu + \Psi D_t + \varepsilon_t, \qquad t = 1,\ldots,T, \tag{9}$$

where X_t is a p x 1 vector of stochastic variables, k is the number of the lags, $\varepsilon_1,\ldots,\varepsilon_t$ are $niid(0,\Sigma)$, and D_t is a vector of nonstochastic variables, such as seasonal dummies or intervention dummies, or stochastic variables that are weakly exogenous that can be excluded from the cointegration space. Equation (9) may be reformulated in the vector error-correction form (VECM):

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi X_{t-1} + \Pi_1 t + \mu + \Psi D_t + \varepsilon_t \tag{10}$$

where Γ refers to parameters of short-run relation, cointegration will appear if Π has reduced rank ($r < p$, which determines the number of cointegration vectors) in which case we can write $\Pi = \alpha\beta'$ where α and β are $p \times r$ matrices of full rank. This hypothesis implies that ΔX_t is stationary, X_t is nonstationary, but $\beta' X_t$ is stationary. Thus, the relations can be interpreted as stationary relations in the long-run among nonstationary variables, which in our case, are the fundamental variables and *reer*. Matrix β defines the cointegrating space and *r* relations; the α matrix is interpreted as the adjustment matrix, indicating the speed with which the system converges to the long-run equilibrium level of the exchange rate.

Now by assuming $\Pi_1 = \alpha\gamma'$, the quadratic trend generated by Eq. (10) can be eliminated and the reduced rank involves the combined matrix $(\Pi, \Pi_1) = \alpha(\beta', \gamma')$. The model with a linear trend (in both level and 1st-difference variable) can be written as:

$$\Delta X_t = \alpha(\beta' X_{t-1} + \gamma' t) + \mu + \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Psi D_t + \varepsilon_t \qquad (11)$$

which is the starting point of Johansen *et al.* (2000) and called $H_l(r)$. Two other models can be defined by restricting the parameters γ and μ. When $\gamma = 0$, we have

$$\Delta X_t = \alpha\beta' X_{t-1} + \mu + \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Psi D_t + \varepsilon_t \qquad (12)$$

which means the process only has a linear trend in the level variable, and denoted $H_{lc}(r)$; if $\gamma = 0$ and $\mu = \alpha\rho'$, then

$$\Delta X_t = \alpha(\beta' X_{t-1} + \rho') + \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Psi D_t + \varepsilon_t \qquad (13)$$

and this process has no linear trend in any direction. Now the model is divided into subperiods according to the position of break points. Suppose the model has *q* subperiods, of length $T_j - T_{j-1}$ for $j = 1,\ldots,q$ and $0 = T_0 < T_1 < T_2 = T$. The last observation in the j^{th} subperiod is T_j even as $T_j + 1$ is the first observation in subperiod $(j + 1)$. Therefore, the model is reformulated conditionally on the first *k* observation of each subperiod, and is given by:

$$\Delta X_t = \left(\Pi, \Pi_j\right)\begin{pmatrix} X_{t-1} \\ t \end{pmatrix} + \mu_j + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Psi D_t + \varepsilon_t \qquad (14)$$

for $j = 1,\ldots,q$ and $T_{j-1} + k < t \leq T_j$. The innovations are assumed to be $niid(0,\Sigma)$. Π, Γ_i and Σ relate to the stochastic component that are the same in all subperiods; whereas the vectors Π_j and μ_j relating to the deterministic component and could be different in each subperiod. The cointegration hypothesis can be formulated in terms of the rank of either Π alone or in conjunction with $\Pi_1,\ldots,\Pi_q$ according to the need of interpretation. The procedures for testing the cointegration rank are presented in Johansen (1995) and the modified procedure taking into account the structural break(s) in Johansen *et al.* (2000). In this study, the analysis and related hypothesis testing have been done using MALCOLM 2.95 (Mosconi, 1998).[16]

16. All the cointegrating analysis can be implemented in a user friendly menu-driven environment, see Oxley (2000) for an overview and practice with this RATS-based suite of procedures.

4. Selection of variables and data

4.1. Variables

Because it does not rely on any specific model of exchange rate determination, the BEER approach is considered as very general for the modeling of equilibrium exchange rates (Clark and MacDonald, 1998). The guidance of other theories is however needed to choose the determinants for the econometric specification.

Two main models of real exchange rate determination are widely used in the literature. First, building on the decomposition of real exchange rate in two different relative prices, Alberola *et al*. (2000) and Alberola (2003) derive an extended version of the stock-flow model presented in Faruqee (1994), to explicitly account for the role of sectoral evolutions.[17] In this approach, the real exchange rate is expected to be a positive function of the net foreign asset position (NFA) and a positive function of the relative productivity differentials in the tradable relative to the nontradable sector, commonly known as Balassa-Samuelson effect (Balassa, 1964; Samuelson, 1964).[18] [19] These two variables are widely used to estimate the misalignment of real exchange rate both for developed and developing countries.

The other model was developed by Montiel (1999) who adopts a "stock" rather than a "stock-flow" approach. One of the advantages of Montiel's model is that it encompasses various analytical frameworks that were previously used to discuss the determinants of equilibrium exchange rates in developing or emerging market countries (e.g., Edwards, 1989). In his approach, the equilibrium exchange rate is compatible with steady-state equilibrium for the economy's net international creditor (or financial) position. This implies that the NFA shall not appear among the set of conditioning long-run fundamentals that includes instead only exogenous and policy variables. Among these determinants and besides the variables relating to the Balassa-Samuelson effect, he also identified changes in the international economic environment, commercial policy, and fiscal policy.[20] This study implements both theories by taking into account all of these model-based fundamentals. The variables determining BEER are chosen by further considering empirical applicability and the availability of the data. These variables are widely used for estimating the real equilibrium exchange rate for both developed and developing countries, Table 1 shows a series of studies that include these explanatory variables.

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17. Two different relative prices refer to relative price of traded goods, and relative price of nontraded to traded goods in the home country relative to the foreign country.

18. As for *NFA*, continuous current account deficit will reduce the net foreign asset position or even raise the net foreign credit. This requires the future trade surplus to compensate it. The depreciation of real exchange rate is favorable to generate this surplus. Therefore, the deterioration of net foreign asset position will cause the depreciation of real exchange rate in the medium or long term. Oppositely, the increase of net foreign asset will cause the appreciation of real exchange rate.

19. The Balassa-Samuelson effect states that an increase in the relative productivity of tradables versus nontradables of one country versus foreign countries raises its relative wage, thus increasing its relative price of nontradables and its relative average price, and inducing an appreciation of the real exchange rate.

20. Variables relating to the Balassa-Samuelson effect are identified as domestic supply-side factor in Montiel's terminology.

Table 1 - Variables frequently chosen in literature with BEER approach (non exhaustive)

Variable	Proxy	Frequency	Authors	Country
Relative productivity differentials	TNT	Y	Kakkar and Ogaki (1999)	USA, UK and Italy
		Q	Faruqee (1994)	US and JAP
		Y	MacDonald (1997)	G3
		Y	Clark and MacDonald (1998)	G3
		Q	Clark and MacDonald (2004)	US, CAN, UK
		Y	Alberola *et al.* (2000)	EMU
		Q	Bénassy-Quéré *et al.* (2004)	G20
		Q	Wang (2004)	CHN
		Y	Funke and Rahn (2005)	CHN
		Q	Coudert and Couharde (2005)	21 countries
		Q	Shi and Yu (2005)	CHN
		Q&Y	Bénassy-Quéré *et al.* (2009a, b)	G20
	Relative GDP per person employed	Y	Canzoneri *et al.* (1999)	OECD countries
		Y	Baffes *et al.* (1999)	2 AFR
		Y	Bénassy-Quéré *et al.* (2009)	G20
	GDPP	Q	Clark and MacDonald (1998)*	G3
		Y	Bénassy-Quéré *et al.* (2004, 2009b)	G20
Net foreign asset position	NFA	Q	MacDonald (1997)	G3
		Y	Clark and MacDonald (1998)	G3
		Q	Alberola *et al.* (2000)	EMU
		Y	Clark and MacDonald (2004)	US, CAN, UK
		Q	Zhang (2002)	CHN
		Y	Wang (2004)	CHN
		Y	Bénassy-Quéré *et al.* (2004)	G20
		Q	Funke and Rahn (2005)	CHN
		Q	Shi and Yu (2005)	CHN
		Q	Bénassy-Quéré *et al.* (2009)	G20
Changes of international economic environment: terms of trade	TOT	Y	Faruqee (1994)	US, JAP
		Q	MacDonald (1997)	G3
		Y	Clark and MacDonald (1998)	G3
		Y	Baffes *et al.* (1999)	2 AFR
		Y	Lin (2002)	CHN
		Y&Q	Zhang (2002)	CHN
		Q	Shi and Yu (2005)	CHN
Commercial policy: degree of openness	OPEN	Y	Baffes *et al.* (1999)	2 AFR
		Y	Zhang (2001)	CHN
		Y	Lin (2002)	CHN
		Y	Zhang (2002)	CHN
		Y	Wang (2004)	CHN
		Q	Shi and Yu (2005)	CHN
Fiscal policy	Government fiscal balance	Q	MacDonald (1997)	G3
		Y	Clark and MacDonald (1998)	G3
	Government expenditure	Y	Edwards (1989)	12 Developing countries
		Y	Zhang (2001)	CHN
		Y	Zhang (2002)	CHN

* Rates of growth in real output per person in manufacturing.

Two proxies for Balassa-Samuelson effect are used in this study. The first is the relative price of nontradable to tradable goods (TNT), which is an indirect measure of relative productivity differentials. It is usually measured by the ratio of the consumer price index (CPI) to the producer price index (PPI or WPI) (e.g., Alberola *et al.*, 2000; Alberola, 2003). The reason for such approximation is that the CPI contains more nontradable goods (especially services) than the PPI, as mentioned by Bénassy-Quéré *et al*. (2009a). The PPI covers agricultural and industrial prices for the first commercial transaction. As services are not included in this index, it constitutes an acceptable proxy of the prices of tradable goods. However, this ratio can be influenced by factors unrelated to the Balassa-Samuelson effect, such as relative demand effects, tax changes, or the nominal exchange rate (Bénassy-Quéré *et al.*, 2004; 2009b). Moreover, as some prices are not entirely market-based and because of restrictions on free movement of workers across sectors and regions in China, the Balassa-Samuelson effect may not be valid when this proxy is used. Therefore, we alternatively use GDP *per capita* (in purchasing power parity standard) as a second proxy for measuring relative productivity (Rogoff, 1996; de Broeck and Slok, 2006).

Changes in the international economic environment refer to changes of external terms of trade, the flows of external transfers, the world inflation rate, and the level of world real interest rates. The use of flows of external transfers and the world inflation rate are less common in the literature, and the level of world real interest rates may be not applicable to China because of controls on international capital movements. Hence, we only include terms of trade (TOT) to account for the potential changes in the international economic environment. Improvements in the terms of trade have a positive effect on real exchange rate.[21]

As for policy variables, commercial policy has a negative effect on equilibrium real exchange rate.[22] Following much of the literature (e.g., Elbadawi, 1994; Zhang, 2001), we choose the degree of openness (OPEN) as a proxy. In contrast, fiscal policy has a positive effect through the changes in the distribution of government spending between traded and nontraded goods. Whatever the chosen measures (either fiscal balance or government consumption), this variable is a key component of national savings, which drives the variation of current account when combined with national investment. Those variations induce an appreciation (or depreciation) of the real exchange rate to adjust for the external imbalance. NFA will also capture the effect of fiscal policy on the real exchange rate (MacDonald, 1997), and because quarterly data on government consumption are not available, we do not use any policy variable as the determinant of BEER.

21. Improvement in terms of trade increases national income in terms of imported goods, which in turn may increase demand for tradable goods requiring an appreciation of currency.

22. Trade liberalization or the rise of degree of openness reduces support to import competing industries and resources are channeled to nontraded goods sector, which ultimately results in depreciation. It means that the real exchange rate is affected by degree of openness negatively.

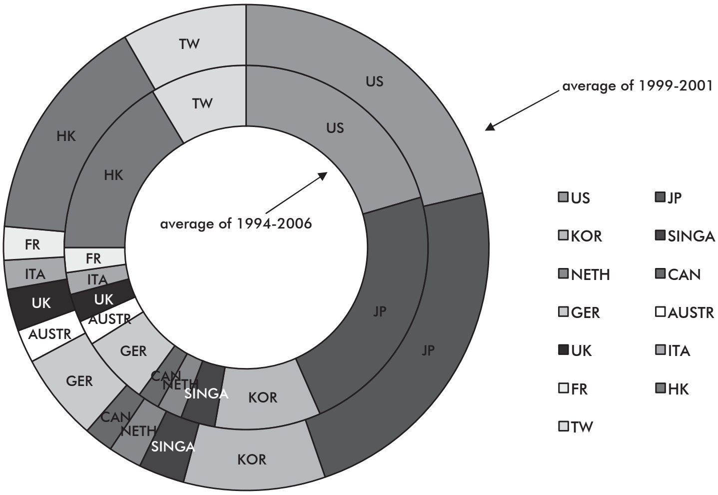
4.2. Data

Data are quarterly and cover the period from 1994Q1 to 2008Q3, with base year 2000 for index series. To preclude the presence of a seasonal unit root (Schwert, 1989), all series used for computing the following variables are seasonally adjusted using the additive X-12 method. The dependent variable is real effective exchange rate (REER), and four explanatory variables are alternative proxies of relative productivity (TNT or GDPP), stock of net foreign assets (NFA), terms of trade (TOT), and degree of openness (OPEN). We will give the definitions of the variables and the way to compute them (the data in logarithm form are expressed in lower case). Evolutions of these variables are shown in Figure 2 and the data sources in Appendix 1.

Trade weights: Before defining the variables in the regression equation, we define and calculate trade weights. Because the three variables defined in the following paragraphs are trade-weighted, appropriate and easy-to-operate weights are pivotal. This is the first contribution of this article. We increase the number of countries involved in the calculation of the real effective exchange rate to thirteen.[23] This allows taking into account a greater impact of partner countries on this rate. We calculate the weights according to the ratio of each partner country's foreign trade with China relative to the total foreign trade of these countries with China: $W^i = \dfrac{Trade^i}{TTrade}$. is the trade weight (percentage) of China's trader partner i; $Trade^i$ is external trade (the sum of exportation and importation) of China with the country i; *TTrade* is the total foreign trade of these countries with China. The final weight of each country calculated here is an arithmetic average weight from 1999 to 2001. Furthermore, we calculated the arithmetic average weight from 1994 to 2006 (the sample period) for each partner country and compared them with the three-year average (see Figure 1). It was found that these two kinds of average weights are very close for these countries. The biggest difference is limited to 1 percent scale (for the case of Hong Kong, U.S. and Japan). This proves that it is plausible to choose this three-year averaged weight to calculate the *REER* and some variables defined below.

23. The thirteen largest trade partners are chosen according to the amount of bilateral trade (import plus export) of each one with China, they are: U.S.A., Japan, Germany, Taiwan, Hong Kong, France, Italy, Britain, Canada, Korea, Netherlands, Singapore, Australia. The ratio of the total external trade with these thirteen countries is high in the sample period, ranging from 66.3 percent to 81.6 percent.

Figure 1 - Trade weights of China's thirteen biggest partners



Real Effective Exchange Rate (REER): This is a CPI-based trade-weighted real effective rate. Including more trade partners in the sample, *REER* calculated with the weights mentioned in the previous paragraph refers to a *more precise* rate of RMB:

$$REER = \prod_{i=1}^{13}\left[\frac{S^{China}\cdot CPI^{China}}{S^{i}\cdot CPI^{i}}\right]^{W^{i}}$$

$$reer = \ln REER = \sum_{i=1}^{N=13} W^{i}(s^{China} + cpi^{China} - s^{i} - cpi^{i})$$

S^{China} (S^{i}) is the bilateral exchange rate of RMB (country *i*'s currency) against USD (USD price of one unit of partner country's home currency). The rise of S^{China} (S^{i}) means the appreciation or revaluation of Chinese (country *i*'s) currency, verse versa.[24] CPI^{China} (CPI^{i}) is the CPI of China (partner country *i*).[25]

Relative price of nontradable to tradable goods (TNT): This variable is defined as the ratio of domestic CPI to the domestic producer or wholesale price index (PPI or WPI) relative to the equivalent foreign effective ratio (trade weighted):

$$TNT = \frac{CPI^{China}/PPI^{China}}{\prod_{i=1}^{13}(CPI^{i}/PPI^{i})^{W^{i}}}$$

$$tnt = \ln TNT = (cpi^{China} - ppi^{China}) - \sum_{i=1}^{N=13} W^{i}(cpi^{i} - ppi^{i})$$

24. But these rates are not available for France, Germany, Italy, and Netherlands after the birth of Euro. Using the conversion rate of Euro to their national currency and exchange rates of Euro against the dollar, we calculate their bilateral exchange rate against the dollar for the period 1999Q1 to 2008Q4.

25. See Appendix 1 for details of this index and *PPI* of China.

CPI^{China} (CPI^{i}) being defined as above, PPI^{China} (PPI^{i}) is the PPI or WPI of China (partner country *i*) according to the availability of data in each country.

Relative GDP per capita (GDPP): It is the ratio of real GDP *per capita* (in purchasing power parity standard) relative to effective (trade weighted) real GDP *per capita* of thirteen partners countries:

$$GDPP = \frac{GDPpc^{China}}{\prod_{i=1}^{13}(GDPpc^{i})^{W^{i}}}$$

$$gdpp = GDPpc^{China} - \sum_{i=1}^{13}(GDPpc^{i})^{W^{i}}$$

$GDPpc^{China}$ ($GDPpc^{i}$) is the real GDP *per capita* in purchasing power parity standard of China (country *i*).

Net Foreign Assets Position (NFA): It is defined as the ratio of the stock of NFA to current price GDP: $NFA = \frac{NetForeignAsset}{GDPA}$. *NetForeignAsset* is those of China; *GDPA* is quarterly cumulated current price GDP of China. Because the NFA series are not directly observable, the cumulative current account balances is used as proxy: as suggested by Lane and Milesi-Ferretti (2001), one takes an initial value of the stock of NFA and adds up current account balances to determine the time series.[26] However, for China, we neither have this initial stock, nor quarterly balance of current account.[27] Therefore, *NetForeignAsset* is extracted from the database of Lane and Milesi-Ferretti (2001), updated using annual current accounts for the year 2008 and interpolated quarterly.[28]

Terms of Trade (TOT): This variable is defined as the ratio of domestic export price index (EX) over the domestic import price index (IM) relative to the equivalent foreign effective ratio (trade weighted).

$$TOT = \frac{EX^{China}/IM^{China}}{\prod_{i=1}^{13}(EX^{i}/IM^{i})^{W^{i}}}$$

$$tot = \ln TOT = (ex^{China} - im^{China}) - \sum_{i=1}^{N=13} W^{i}(ex^{i} - im^{i})$$

EX^{China} (EX^{i}) is the export price index of China (partner country *i*); IM^{China} (IM^{i}) is the import price index of China (partner country *i*).

Degree of Openness (OPEN): It is measured as the ratio of the sum of imports and exports over GDP in domestic currency and is included to capture the effect of commercial

26. Following the method of Lane and Milesi-Ferretti (2001), Funke and Rahn (2005) obtained quarterly series of current account balances by interpolating the annual ones. Shi and Yu (2005), alternatively, took the stock of foreign exchange reserves of 1990 as the initial value of the stock of NFAs at the beginning of 1991 and cumulatively added to the initial stock the quarterly trade balances, which are taken as the proxy of current account balances.

27. Chinese current account data was only available on an annual basis; however, from 2000, the State Administration of Foreign Exchange (SAFE) of China began to publish the Balance of Payments every six months.

28. See "Updated and extended version of the External Wealth of Nations Mark II database" that they developed.

policy: $OPEN = \frac{EXP + IMP}{GDP}$. *EXP* (*IMP*) is exportation (Importation) and *GDP* is Gross Domestic Product of China in current price.

5. Results

5.1. Univariate unit roots analysis

Before cointegrating relations are tested for above-mentioned variables, we should ensure that every variable entering into the cointegrating vectors is at most I(1) by implementing stationary or unit root tests. Following Mosconi (1998), we implement univariate analysis by some efficient unit root tests developed by Elliott *et al*. (1996, ESR) and by Ng and Perron (2001, NP), and an endogenous two-break Lagrange multiplier unit root test by Lee and Strazicich (2003, LS).[29] [30]

The traditional ADF and PP tests are not implemented because it is generally admitted that they suffer from severe size distortion (in the direction of over-rejecting the null) when the series has a large negative moving average root (e.g., Schwert, 1989; Ng and Perron, 2001); they have low power against the alternative hypothesis that the series is stationary (or TS) with a large autoregressive root (e.g., Dejong *et al.*, 1992). Also, the power of these tests diminish as deterministic terms (constant and/or trend) are added to the test regressions. However, the NP tests are robust to the presence of additive outliers, without serious size distortions relative to ERS test.[31]

The visual inspection of the variables revealed possible break points in the series (Figure 2). In line with the framework of cointegrating analysis in presence of structural breaks in the trend, we use a minimum Lagrange multiplier (LM) unit root test proposed by Lee and Strazicich (2003, LS), which endogenously determines the location of (up to) two structural breaks in level and trend, and tests the null of a unit root, without diverging in the presence of breaks under the null.[32] [33]

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29. Mosconi recognizes two extreme points of view expressed in the literature on how univariate unit root analysis is related to multivariate cointegration analysis: i) univariate analysis is needed as a preliminary step by citing Engle and Granger (1987); ii) univariate analysis is unnecessary and potentially misleading by citing Johansen (1991). Although stating that the general philosophy of MALCOLM is consistent with the second viewpoint, the author of the software thinks that univariate analysis may be of some use as a preliminary step to have a rough idea of the dynamic properties of the time series at hand (see Mosconi, 1998, p. 45-46).

30. See Appendix 2 for the detail of LS test.

31. See Darné and Diebolt (2004) for simulation experiments. Based on this fact, we report only the results of NG test. Those of ERS test are available upon request.

32. Following the seminar article of Perron (1989), subsequent studies (e.g., Lumsdaine and Papell, 1997; Zivot and Andrews, 2002) modified his test to allow for one or two unknown breakpoints that are endogenously determined from the data, assuming, in contrast to the LM test used in this article, no break(s) under the unit root null. Consequently, in the presence of a break under the null, one might incorrectly conclude that rejection of the null indicates evidence of a trend-stationary time series with breaks, when in fact the series is difference-stationary with breaks.

33. The alternative approach to deal with the structural changes for preventing the UR test from being biased lies in detecting shocks in the form of outliers and then applying some efficient UR tests on the series corrected by previously detected outliers. For details of the methodology and applications, see Darné and Diebolt (2004).

Figure 2 - The REER and its fundamentals (level and 1st-difference)

Different results of NG and LS tests for the sample period 1994Q1-2008Q3 are shown in Tables 2 and 3.[34] The former shows the nonstationarity at the level for each variable (upper part of Table 2) and stationarity in the 1st-difference only for *tnt*, *gdpp*, and *NFA* (lower part of Table 2). Nonrejection of the null hypothesis of unit root for other 1st-difference variables maybe arise from the problem of size distortions of NP test in the presence of structural breaks. The results of the latter partly confirm this conjecture.

By introducing break(s), one can reject the null hypothesis for *reer* and *OPEN*, but only at borderline values (at 10 percent) for *tot* (lower part of Table 3).[35] For the level variables, one-break (or "Non-break") LM unit root test appears more appropriate for *tnt* and *OPEN* (or *gdpp*) and showed their nonstationary property. The rejection of unit root for *reer* and *NFA* at borderline values means that one cannot clearly distinguish I(1) of these variables from trend stationarity.

Evidence from both the NP and LS tests seems to suggest that these variables are at most I(1), implying that the series are stationary in the first-difference. The eventual cointegrating relation(s) can be investigated in the framework discussed in subsection 3.2.[36]

Table 2 - Ng-Perron(NP) unit root test

Variable	*MZa*		*MZt*		Lags
	With Trend	With Intercept	With Trend	With Intercept	
Level					
reer	–8.02396		–1.40918		1
tnt	–4.03928		–1.99764		0
gdpp	–2.38245		–0.99508		10
NFA	–1.30549		–0.52881		0
tot	–5.22505		–1.61631		4
OPEN	–3.92872		–1.26522		0
1st-difference					
reer	–2.69709	–2.11489	–1.03686	–1.00627	5 (5)
tnt	–28.9585***	–0.37046	–3.80298***	–0.35065	0 (10)
gdpp	–6.55816	–6.92255*	–1.67175	–1.70966*	4 (4)
NFA	–20.8768**	–8.51441**	–3.22872**	–2.05212**	1 (3)
tot	–9.13048	–1.93931	–2.12564	–0.91039	0 (5)
OPEN	–3.43311	–11.5953	–1.49903	–5.01327	3 (4)

*,**, and *** denote significant at 10%, 5%, and 1% levels, respectively; lags in braces are those for models with intercept.

34. Repeating this two-break LM test on smaller subsamples for checking the robustness of the result could be considered once longer horizon series are available.

35. On the contrary, if one considers the linear trend without break more appropriate for *gdpp*, one can reject the unit root hypothesis unless we raise the significance level up to 20 percent.

36. The stationarity of 1st-difference variable of *gdpp* and *tot* can be checked later in the cointegrating framework.

Table 3 - LM (LS) unit root tests (Lag max=8)

Variables	$\hat{k}$	$\hat{T}_B$	Test statistic	Critical value Break points
Level				
reer	6	1998:02 , 2006:03	−6.28206**	λ = (0.3,0.8)
tnt	2	1998:02n, 2006:03	−6.51667***	λ = (0.3,0.8)
	2	1998:04	−3.85862	λ = 0.3
gdpp	8	1998:04 , 2003:01	−11.19604***	λ = (0.4,0.7)
	6	No break	−2.15411	−2.77 (at 10%)
NFA	4	1998:01 , 2000:04	−6.04242**	λ = (0.3,0.5)
tot	7	1997:02 , 2003:02	−5.29261	λ = (0.2,0.6)
	5	2000:04 , 2006:01n	−4.73323	λ = (0.5,0.8)
OPEN	5	2001:02	−2.69147	λ = 0.5
1st-difference				
reer	1	1998:03 , 2001:03	−8.19884***	λ = (0.3,0.5)
tnt	0	1996:04 , 2006:03	−7.37016***	λ = (0.2,0.8)
gdpp	8	1998:01 , 1999:04	−8.85234***	λ = (0.3,0.4)
	5	No break	−2.70512	−2.77 (at 10%)
NFA	0	1996:04n, 2006:03	−7.07634***	λ = (0.2,0.8)
	4	2007:03	−4.66304**	λ = 0.8
tot	7	1996:04 , 2003:03	−5.30189	λ = (0.2,0.7)
OPEN	0	2000:01 , 2007:03	−10.77576***	λ = (0.4,0.8)

Notes: $\hat{k}$ is the optimal number of lagged first-differenced terms included in the unit root test to correct for serial correlation. $\hat{T}_B$ denotes the estimated break points. *n* denotes that the identified break point was not significant at the 10% level. Critical values are shown below for the two(one)-break minimum LM unit root test with linear trend (Model C) at the 1%, 5%, and 10% levels for a sample of size T = 100, respectively, depending on the location of the breaks $\lambda = (T_{B1}/T, T_{B2}/T)$. The critical values for LM test with breaks come from Table 2 in Lee and Strazicich (2003) and Lee and Strazicich (1999); those of LM test without break come from Table 1 of Lee and Strazicich (1999).

*, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Break points timing		Critical values 1%	5%	10%
Two breaks: $\lambda = (T_{B1}/T, T_{B2}/T)$	λ = (0.2,0.4)	−6.16	−5.59	−5.27
	λ = (0.2,0.6)	−6.41	−5.74	−5.32
	λ = (0.2,0.8)	−6.33	−5.71	−5.33
	λ = (0.4,0.6)	−6.45	−5.67	−5.31
	λ = (0.4,0.8)	−6.42	−5.65	−5.32
	λ = (0.6,0.8)	−6.32	−5.73	−5.32
One break: $\lambda = (T_B/T)$	λ = 0.1	−5.11	−4.50	−4.21
	λ = 0.2	−5.07	−4.47	−4.20
	λ = 0.3	−5.15	−4.45	−4.18
	λ = 0.4	−5.05	−4.50	−4.18
	λ = 0.5	−5.11	−4.51	−4.17

5.2. Cointegration analysis with structural break(s)

To begin the cointegration analysis, I estimate a *p*-dimensional Vector Autoregressive Model (VAR) for which inclusion of the linear trend and its characteristic (number of breaks) must be predefined. The results of LS test fail to provide an obvious evidence for choosing the number of breaks (one or two are both possible) of the system. Furthermore, neither the trend(s) nor the timing of breaks is necessarily the same as in the univariate unit root (UR) analysis reported in Table 3. As suggested by Johansen *et al.* (2000), instead of relying on the dates identified in the UR tests, which depend on the given data, dates of breaks should be, on the contrary, determined exogenously under the guidance of historical facts. Combined with the visual inspection of Figure 2, we start by introducing one break that corresponds to the Asian financial crisis that occurred in July 1997.[37] The last observation of the first period is 1997:03. Although Figure 2 shows clearly the presence of trends, one can suspect trends in the 1st-difference variables. Moreover, as the presence of a linear trend in exchange rate seems theoretically inconsistent, we model the data using H_c, meaning that we constrained the constant to lie in the long-run relationship.

To determine the VAR model, which include *reer*, *gdpp*, *NFA*, *dtot* and *OPEN*, the maximum lag analysis is implemented and reported in Table 4.[38] The information criteria suggest different *k*, however, by following the common practice (relying on the Hannan-Quinn criterion), $k = 2$ was chosen, which is also confirmed by LR(2) test.

Table 4 - Maximum lag length analysis (*p*-value for LR1* test)

k	Akaike	Hannan–Quinn	Schwartz	LR(2)
1	–42.775	–42.192	–41.245	NA
2	–43.798	–42.779	–41.121	0.000
3	–43.987	–42.531	–40.163	0.076
4	–44.568	–42.675	–39.597	0.062
5	–45.321	–42.991	–39.202	0.237

* *LR*1 is the likelihood ratio (*LR*) test for lag *k versus* (*k* –1).

In Table 5, Jarque-Bera normality test reports the residual diagnostics of estimated VAR. Some problems of kurtosis are seen for *reer* and *gdpp*, but normality can be rejected only at five percent significance level, not at one percent. The correlograms (not reported here) do not show serial correlation of the residuals, which finally validates specifications of our model.

37. The option of two breaks (T_{B1}=1997:03;T_{B2}=2005:03) are also investigated, with the latter corresponding to China's exchange rate reform in July 2005 discussed in Section 2.

38. *dtot* is reported as I(1) later by test of stationarity, meaning that *tot* is I(2), see Table 9.

Table 5 - Jarque-Bera normality tests (*p*-values)

Equation	Skewness	Kurtosis	SK&Kur.
reer	0.624	0.015	0.046
gdpp	0.863	0.019	0.064
NFA	0.681	0.610	0.807
dtot	0.861	0.038	0.114
OPEN	0.953	0.150	0.355
SYSTEM	0.978	0.002	0.032

The rank tests for cointegration are reported in Table 6 and support $r = 2$, which is not contradictory with our expectation even if these multiple cointegrating vectors may complicate identification and interpretation. The stability of both the cointegration rank and β space are tested and confirmed using MALCOLM. We estimate a model with $r = 2$.

Table 6 - Cointegration rank (*r*) test

Hypothesis	Trace test	*p*-value (95%)
One break: T_B = 1997:03		
$r = 0$	119.94	0.00004
$r \leq 1$	72.26	0.00822
$r \leq 2$	38.15	0.14349
$r \leq 3$	16.27	0.47658
$r \leq 4$	5.60	0.51175

The inclusion of *tnt* do not permit us to specify an appropriate model for estimation (see Table 7). It can be explained by the special behavior of this variable.

Table 7 - Selection of the model (with *tnt*)

Break	*k*	Normality		*r*	Stability of *r*	Stability of β	Variable excluded	Variable weakly exogenous
0	1	Trend	Kur. for *OPEN*	1	Stable	Stable	*dtot*, *OPEN*	*dtot*, *OPEN*
	1	Constant	Yes	5	Stable	Unstable	none	none
T = 1997:03	1	Trend	Kur. for *OPEN*	0				
	1	Constant	Yes	4	Stable	Unstable	*dtot*, *OPEN*	*dtot*, *OPEN*
T_{B1} = 1997:03	1	Trend	Yes	0				
T_{B2} = 2005:03	1	Constant	Yes	2	Stable	Unstable	All except *tnt*	*tnt*, *dtot*, *OPEN*

5.3. Estimation

Table 8 reports the results of some routine tests: each variable in the VAR is nonstationary, which conforms to the results of the univariate analysis of subsection 5.1.[39] None could be excluded from the cointegrating vector, which also proves the appropriateness of including the constant in two subperiods.[40] Only *gdpp* shows some weak exogeneity (see Engle *et al.*, 1983, for an exposition of distinguished exogeneities), implying that it does not respond to last period's deviation from the equilibrium level of the exchange rate.

Table 8 - The "Routine" tests

Variable	Exclusion[a]		Stationarity[b]		Exogeneity[c]	
	$\chi^2(n)$	sig. level	$\chi^2(n)$	sig. level	$\chi^2(n)$	sig. level
reer	16.67355	< 0.01	26.35375	< 0.01	12.00036	0.00248
gdpp	9.90746	0.00706	24.15412	< 0.01	1.39426	0.49801
NFA	10.43815	0.00541	23.86706	< 0.01	11.41818	0.00332
dtot	5.61967	0.06021	15.88529	0.00318	8.47745	0.01443
OPEN	23.36172	< 0.01	23.37376	< 0.01	12.47213	0.00196
Constant1	12.59488	0.00184				
Constant2	12.30994	0.00212				

[a] H_0: Variable can be excluded from cointegrating vectors. Exclusion is accepted when the significance is larger than 0.05.

[b] H_0: Variable is stationary. Stationarity is accepted when the significance is larger than 0.05.

[c] H_0: Variable is weakly exogenous. Exogeneity is accepted when the significance is larger than 0.05.

With the guidance of these results, the following linear restrictions are imposed on α and β', with $\alpha = [A_1a_1, A_2a_2]$ and $\beta' = [B_1b_1, B_2b_2]$; a_i and b_i ($i = 1,\ldots,r$) are unknown parameters to estimate. The restriction matrix for cointegrating vector 1 and 2 are:

$$B_1 = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}, \quad B_2 = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

39. Because it is the 1[st]-difference variable of *tot* that enters in the VAR, the nonstationarity of *dtot* reported in Table 9 confirms the doubts raised by NP and LM test about this variable.

40. Exclusion of *dtot* is only accepted at the borderline value of five percent significance level. In view of its theoretical importance for driving *reer*, we keep it in the cointegrating vectors.

This restriction can be explained as follows: as r = 2, we attempt to restrict the first vector to contain elements driving *reer* (*gdpp*, *NFA* and *OPEN*) and constant in each subperiod, whereas the second vector contains two variables, which represents another long-run relation between the *dtot* (that we interpret as speed of variation of terms of trade), and the *OPEN*, and the constants. The restriction matrix for adjustment vector 1 and 2 are:

$$A_1 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad A_2 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

This restriction imposed on α takes into account the weak exogeneity of *gdpp*.[41] These restrictions are not statistically rejected (with a χ^2-statistics equal to 15.70879) and we get the following equilibrium relationships (with *t*-statistics in parentheses):

$$\begin{aligned} reer = {} & \underset{(2.6240)}{0.6025} \cdot gdpp + \underset{(2.6240)}{0.0493} \cdot NFA - \underset{(-2.8564)}{0.9434} \cdot OPEN \\ & + DU \cdot (\underset{(2.6044)}{2.0477} - 2.0148) + \underset{(2.6245)}{2.01482} \end{aligned} \quad (15)$$

$$dtot = \underset{(-0.7099)}{0.0518} \cdot OPEN + DU \cdot (\underset{(1.2208)}{0.0095} - (-0.0002)) + \underset{(1.1823)}{(-0.0002)} \quad (16)$$

with

$$DU = \begin{cases} 1 & t \le T_B \\ 0 & otherwise \end{cases}$$

2.0477 and 2.0148 are the constant of the first and second subperiod, respectively, in equation (15); 0.0095 and –0.0002 are those in Eq. (16).

Table 9 - Alpha adjustment matrix

Variable	Unrestricted		Restricted	
	α1	α2	α1	α2
reer	–0.2696	0.1683	–0.2634	0.1973
gdpp	–0.0169	0.0111	0.0000	0.0000
NFA	0.2440	–0.0627	0.2530	–0.1237
dtot	–0.0543	–0.5776	–0.0728	–0.5654
OPEN	–0.5350	–0.1976	–0.5573	–0.1982

41. This restriction means to impose the adjustment coefficients of *gdpp* at zero. Table 9 reported the estimated unrestricted α and restricted α for comparison, without showing big difference between them. Notice that the unrestricted adjustment coefficients of *gdpp* are near zero. Imposing this kind of linear restrictions is sometimes used as a mean of improving the stochastic properties of the model (Hansen and Juselius, 1995, p. 12).

5.3.1. Long-run equilibrium exchange rate and misalignment

We note that in the first cointegration relation, all the coefficients have correct signs and are all statistically significant. Consistent with the theory, the Eq. (15) shows that *gdpp* and *NFA* have a positive effect on the equilibrium exchange rate and *OPEN* has negative one. However, for the second one, it shows that the degree of openness has a positive effect on the variation speed of term of trade, implying that the more open a country is, the higher the speed of amelioration or deterioration of its terms of trade is. However, the coefficients are not significant. Thus we concentrate on the first cointegration relation for estimating equilibrium exchange rate and relevant misalignment. Among the determinants of equilibrium exchange rate of RMB, *gdpp* plays a more significant role than the two others. Balassa-Samuelson effect has been proved to be effective for China by using this variable although it is sometimes considered as less precise proxy than *tnt*. However, the failure of specifying an appropriate VAR and/or that of finding plausible cointegration relations when using *tnt* as proxy of Balassa effect may indicate the problematic nature of its behavior. This finding is not contradictory with evidence provided in the literature (e.g., Coudert and Couharde, 2005), which showed the failure of *tnt* to explain the behavior of exchange rate of RMB, implying that the Balassa effect is not verified for China. One explanation pointed out is that the Balassa-Samuelson effect is based on some restrictive assumptions that may not be fulfilled in China. For instance, it concerns the perfect mobility of factors of production, such as internal labor mobility. This condition is necessary to get rising wages in the tradable products sector when productivity in that sector increases and to get a significant spillover of this wage increase into the nontraded sector. Neither a sufficient internal mobility of capital nor a perfect internal labor mobility is satisfied in China. Furthermore, to fight inflation, the administrative control of prices during the nineties made the *CPI* and *PPI* fail to represent the relative change of productivity in the traded and nontraded sectors. All of these could argue that *tnt* is not an appropriate proxy of the Balassa-Samuelson effect for China, at least until now, let alone the inherent default of this variable (see MacDonald and Ricci, 2007).

Using Eq. (15), current equilibrium exchange rate (*beer_cur*) can be calculated. Moreover, according to BEER approach, we have:

$$mis\_cur = (reer - beer\_cur)/beer\_cur \qquad (17)$$

where *mis_cur* is the current misalignment. When misalignment is greater than zero, *reer* is overvalued; otherwise, *reer* is undervalued. Estimated BEER along with the actual real exchange rate (*reer*), and current misalignments are plotted in Figure 3 (upper section). Although the fundamentals can account for most of the movements in the RMB, the most striking feature of these two figures is the degree of misalignment in the second subperiod (1998-2007). RMB is overvalued during most of the period, and this is totally opposite to the previous explanations that report undervaluations of RMB to different extents. An initial explanation can be the following: as the current value of economic fundamentals themselves may not be at their long-run equilibrium level, it is useful to calculate the permanent equilibrium exchange rate by their long-run values. A common practice to calibrate these variables at long-run values is, when using BEER approach, to use some sort of statistical filter, such as

Hodrick-Prescott (HP) filter to obtain smoothed series for economic fundamentals (see, e.g., Clark and MacDonald, 1998, for application of this filter).[42] In view of our short data span of fifteen years, considering the fluctuations in the range from one year and a half to eight years, which corresponds to a business cycle, seems plausible. Therefore, we employ the HP filter to calculate the long-run equilibrium exchange rate and compare it with those given by the variables of the economic fundamentals filtered by CF filter.[43] Therefore, the total misalignment can be calculated by the following equation:

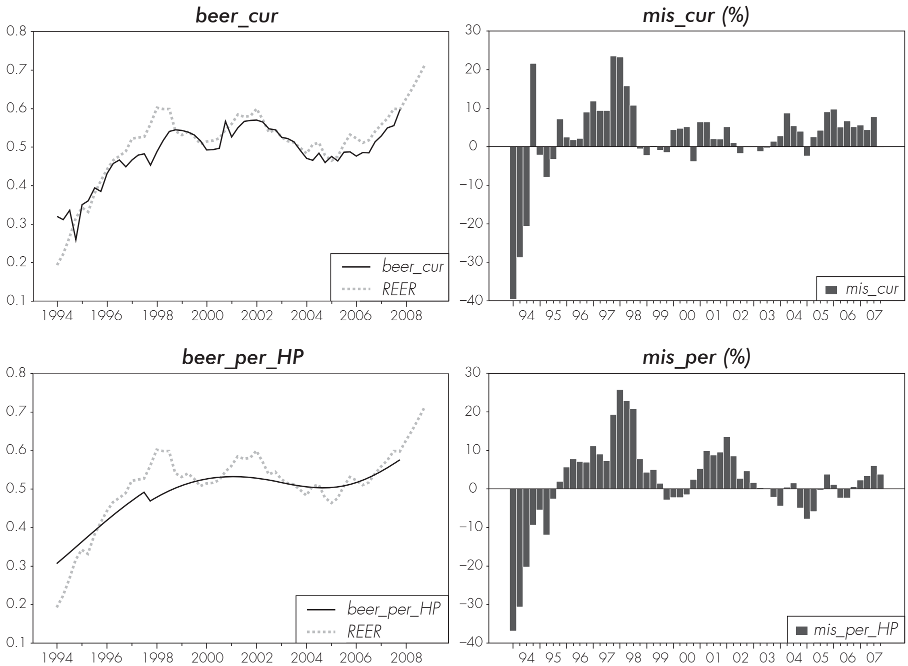
$$mis\_per = (reer - beer\_per)/beer\_per \qquad (18)$$

mis_per is the long-run misalignment, *beer_per* is the long-run equilibrium exchange rate, and both of them are reported in Figure 3 (lower section). In the first subperiod, the results reported are basically consistent with that of current equilibrium exchange and current misalignment, but they showed some differences for the second subperiod. From the end of 2002, the undervaluation of RMB began to increase, reaching 8 percent just before the reform of exchange rate regime occurred in July 2005. After this reform, the one-time revaluation of 2.1 percent and consecutive appreciations of RMB have reduced the misalignments and even reversed them: some mild overvaluations were exhibited until 2007Q4. These obvious differences between current and permanent equilibrium exchange rate and misalignments reflect the impact of business cycle on fluctuation of economic fundamentals.

42. However, as for obtaining certain frequency component of data, there is a keen debate on the use of filters (see, e.g., Christiano and Fitzgerald, 2003). They developed an optimal finite-sample approximation (CF filter hereafter in this article) to the band pass filter and compared it with several alternatives, such as HP filter, the band pass filter recommended by Baxter-King. Although the CF filter can handle different frequency components of data, "HP filter appears to do just fine for one interested in statistics base on business cycle and higher-frequency components of quarterly data".

43. Meanwhile, the Beveridge-Nelson and the more recent Granger-Gonzalo decomposition have been used for decomposing the series into permanent and transitory components, but they correspond to, exactly speaking, the permanent equilibrium exchange rate approach (PEER), which is out of range of this article.

Figure 3 - BEERs and misalignments of RMB



Source: Author's calculation.

5.3.2. The vector error correction model: short-term dynamics

The representation of an error correction model similar to Eq. (11) can be used if $r \geq 0$. Because *reer* has two cointegration relationships with economic fundamentals, a vector error-correction (VEC) model describing the adjustment mechanism of the exchange rate from short-term to long-term is estimated (Table 10). VEC allows long-run components of variables to obey equilibrium constraints imposed by cointegrating relationships while short-run components have a flexible dynamic specification (Engle and Granger, 1987). The cointegration term is known as the error correction term because the deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments. The adjustment matrix α corresponding to Eqs. (15) and (16) are reported in Table 9. The larger the absolute value of adjustment coefficient, the faster is the adjustment speed. The real exchange rate adjusts negatively to disequilibrium in the first cointegrating vector, meaning that the exchange rate moves to close the gap of disequilibrium by approximately 26 percent per quarter, forced by error correction term. In the short run, the real effective exchange rate is only influenced by *gdpp*, with a unidirectional effect as in the long-run. Other two determinants of *reer* only have their effects in long-run. Therefore, the rise in the GDP *per capita* would lead to the appreciation of the real effective exchange rate in the short run.

Table 10 - Vector error correction model (t-stat. in parentheses)

Error correction:		$\Delta reer_t$	$\Delta gdpp_t$	ΔNFA_t	$\Delta dtot_t$	$\Delta OPEN_t$
Level coef.	$reer_{t-1}$	–0.2634	0.0000	0.2530	–0.0728	–0.5573
		(–2.6240)	(NA)	(2.0712)	(–1.1832)	(–4.4443)
	$gdpp_{t-1}$	0.1587	0.0000	–0.1525	0.0439	0.3358
		(2.6240)	(NA)	(–2.0712)	(1.1832)	(4.4443)
	NFA_{t-1}	0.0130	0.0000	–0.0125	0.0036	0.0275
		(2.6240)	(NA)	(–2.0712)	(1.1832)	(4.4443)
	$dtot_{t-1}$	0.1973	0.0000	–0.1237	–0.5654	–0.1982
		(1.0660)	(NA)	(–0.5491)	(–4.9856)	(–0.8576)
	$OPEN_{t-1}$	–0.2587	0.0000	0.2451	–0.0394	–0.5155
		(–2.8564)	(NA)	(2.2237)	(–0.7099)	(–4.5563)
	Constant1	0.5375	0.0000	–0.5170	0.1544	1.1430
		(2.6044)	(NA)	(–2.0581)	(1.2208)	(4.4336)
	Constant2	0.5308	0.0000	–0.5099	0.1465	1.1228
		(2.6245)	(NA)	(–2.0715)	(1.1823)	(4.4446)
1st-dif. coef.	$\Delta reer_{t-1}$	0.3651	0.0021	–0.1398	0.1443	–0.0814
		(2.7626)	(0.1050)	(–0.8627)	(1.6934)	(–0.4930)
	$\Delta gdpp_{t-1}$	0.9197	0.9363	0.2894	–0.5406	0.4184
		(3.0689)	(24.700)	(0.7896)	(–2.8433)	(1.1176)
	ΔNFA_{t-1}	–0.1249	0.0076	0.3480	–0.0992	0.2723
		(–1.3003)	(0.4587)	(2.9491)	(–1.5826)	(2.2683)
	$\Delta dtot_{t-1}$	–0.2676	–0.0594	0.0299	0.3016	–0.0606
		(–1.3589)	(–1.9058)	(0.1237)	(2.3694)	(–0.2461)
	$\Delta OPEN_{t-1}$	0.1546	–0.0006	0.2531	0.0319	–0.1807
		(1.6614)	(–0.0394)	(2.2148)	(0.5264)	(–1.5537)
	D_{t-1}	0.5754	0.0060	–0.5191	0.1332	1.1581
		(2.7695)	(2.0392)	(–2.0528)	(1.0460)	(4.4626)
	D_{t-2}	0.5779	0.0062	–0.5256	0.1157	1.1412
		(2.7764)	(2.0651)	(–2.0748)	(0.9068)	(4.3892)

5.3.3. A comparison

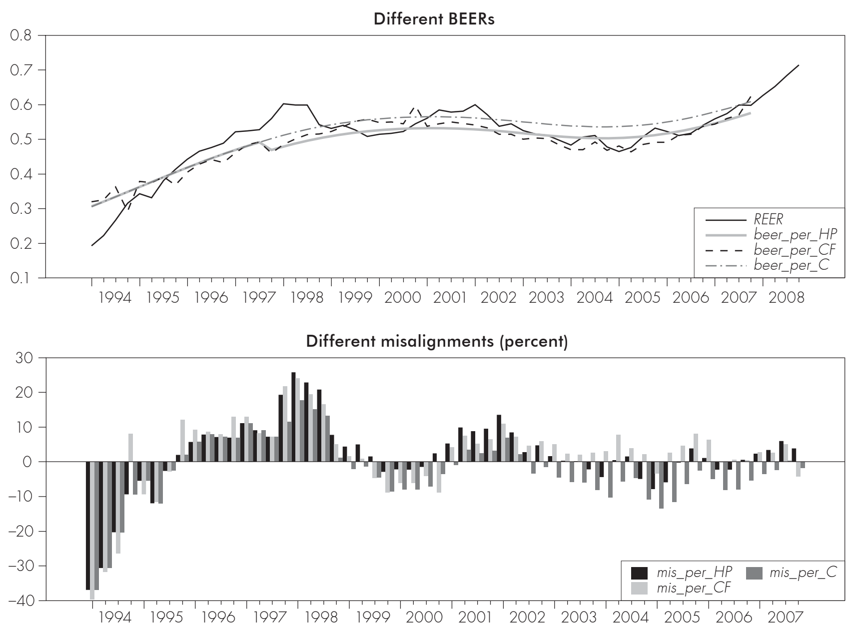
As mentioned in the introduction, this article employs a new empirical framework (cointegrating analysis with structural breaks) to estimate the BEER of RMB; this difference of method should also be able to explain the divergence of our results with those of previous studies that used the cointegrating framework without structural break.[44] Precisely, as only the vectors referring to the deterministic component (constants in this article) could be different in each subperiod (discussed in subsection 3.2), the two different constants in Eq. (15), rather than only one, may be one reason of the divergence. To confirm this conjecture, we calculate a counterfactual *beer*, denoted as *beer_per_c*, by modifying Eq. (15). For calculating it, we use the constant of the first subperiod for the whole sample and report it in Figure 4 along

44. Previous studies belong to BEER approach.

with *beer_per_HP*. By taking into account the structural break, our equilibrium exchange rate (*beer_per_HP*) recorded a slump in face of the external shock of the Asian financial crisis. The sudden drop in the level of exchange rate is represented by a smaller constant in the second subperiod, which is not the case for the counterfactual *beer* (*beer_per_C*). Obviously, from 1997Q4, *beer_per_C* is always higher than *beer_per_HP*, and consequently, the misalignments derived from *beer_per_C* is greater when RMB is undervalued, or smaller when RMB is overvalued. Notice that the undervaluations obtained from *beer_per_C* in 2004 and 2005 are as high as 15 percent, which is more consistent with the extent of undervaluation of RMB in the literature.

Furthermore, we calculate another *beer* by using the CF method to filter the fundamentals (denoted as *beer_per_CF*). This *beer* and its relevant misalignment are also reported in Figure 4 along with two other *beer*s (or misalignments). As for *beer_per_CF*, it is less smooth than the *beer_per_HP* but much nearer to the *reer* from 2000; the misalignment showed the overvaluation of RMB almost during the entire subperiod post-2000. These differences of results come from the effect of the different filters on economic fundamentals. As mentioned earlier, in addition to the frequency component dealt by HP filter, CF filter can handle other frequency components of data, which may be unnecessary for our relative short span of data. Moreover, the persistent overvaluation, although to a small extent, seems difficult to interpret economically. Thus, we argue that choosing HP filter to calibrate the fundamentals to sustainable values appears more appropriate than CF filter for China with a limited data span.

Figure 4 - Comparisons of BEERs and misalignments



Source: Author's calculation.

6. Interpretations

In this part, we discuss the evolution of equilibrium exchange rate and relevant misalignment during the sample period. From 1994Q1 to 1997Q3, RMB equilibrium exchange rate exhibited a steady appreciation that is the result of the co-influence of its economic fundamentals. Precisely, during this subperiod, *gdpp* continued rising, which confirms the Balassa-Samuelson effect. *NFA* declined a bit and began to increase. The climb of NFA originated principally from the trade surplus during this period, whereas the drop of the *OPEN* resulted from the contraction of the growth of foreign trade, which is caused by the soft landing of China's economy at that moment and by the impact of the Asian financial crisis.[45] That shock is reflected by the drop of the constant at one stroke, whereas it could not prevent the equilibrium exchange rate from appreciating. Although *OPEN* began to soar from 1998Q3, implying that *beer_per* would depreciate, the *beer_per* continued to rise because it was driven by the growth of *gdpp* and *NFA*, which were driven principally by the dynamics in the manufacturing sector and the surplus of current accounts of China, respectively. Of course, the *gdpp* and *NFA* were affected, but to a limited extent. Thus, the effect of quick growth of *gdpp* and *NFA* compensates the pressure of depreciation because of the rise of *OPEN*. However, from the beginning of 2001 to 2005, the *beer_per* had depreciated to some extent. During this period, the rise of *gdpp* and *NFA* (especially in 2001 and 2003) had decelerated and the degree of openness increased rapidly. On the one hand, for *gdpp*, as this variable is PPP based, the deceleration of growth was a consequence of the rise of the consumer price (CPI) of China relative to other partner countries. As regards *NFA*, the continuous depreciation of the USD from 2002, the strong growth of China's GDP, and the smaller contribution of exportation to GDP, all led to the decrease of the variable. On the other hand, *OPEN* began to rise from the end of 1998; the main reason for this rise is the growth of external trade of China that had resumed after the Asian financial crisis and had increased more quickly than that of GDP. After the reform of exchange rate regime in July 2005, the growth of *gdpp* accelerated thanks to lower inflation; *NFA* increases with fluctuations, the potential reasons of which are wealth effect of the depreciation of USD against RMB, the entry of hot money, and the permission for investors to invest in foreign securities markets (only *via* QDII); the degree of openness increased slowly and even declined because of the impact of appreciation of RMB on the foreign trade of China.[46] All of these movements prompt an increase in the equilibrium exchange rate.

With regard to the fluctuations of misalignment, it can be explained through the movements of *reer*. From 1994Q1 to 1997Q3, *reer* increased more quickly then *beer_per_HP* did and led to overvaluation of some extent. There are two main reasons: inflation rate in

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45. From 1994 to 1998, in order to prevent the economy from overheating, Chinese government had taken the initiative of controlling the high inflation rate, and successfully achieved a soft landing. China's GDP has increased continually, even until 1998 (The period of crisis); the growth rate still has been kept high to 7.8 percent. However, the extent to which the growth of external trade had been contracted due to the soft landing was higher than that of contraction of overall economic growth.

46. QDII (Qualified Domestic Institutional Investors) is an investment scheme under which domestic institutional investors authorized by the government could invest in the overseas capital markets

China had been much higher than in the other partner countries from the first quarter of 1994 to the second quarter of 1996; the shock of the Asian financial crisis had made the currencies of partner countries in this region depreciate against USD, implying appreciated *reer* because it is pegged to the USD. After this shock, *reer* continued to rise (but not the *beer_per_HP*) although there was a relatively lower inflation in 1996, magnifying the overvaluation. From 1998, currencies of the countries that suffered from Asian financial crisis had started to appreciate against the USD; meanwhile the Chinese monetary authorities had pegged RMB to the dollar. Thus the *reer* had depreciated under a very low inflation rate in China relative to other partner countries, reducing the extend of overvaluation. From 1999Q4 to 2002Q1, USD appreciated against most currencies of the partner countries, leading to the rise of *reer* because the RMB was pegged, and corresponding overvaluation of some extent in view of the relatively stable permanent *beer*. Still because of this peg, the overall depreciation of USD from 2002 prompted a decrease of the *reer* and reduced this misalignment. Finally, the continual depreciation of dollar went as far as to cause a lower *reer* than the permanent *beer* in the middle 2005. Thereafter, the revaluation of 2.1 percent and consequent appreciations of RMB against USD, and a higher domestic inflation rate resulted in a slight overvaluation.[47]

7. Concluding remarks

In this article, using the behavioral equilibrium exchange rate (BEER) approach, we estimate the equilibrium real exchange rate of Renminbi (RMB) and the exchange rate misalignment in China, for the period from 1994Q1 to 2007Q4. Estimation and hypothesis testing are implemented with the more general cointegration framework where the presence of structural breaks in the deterministic trend or constant is taken into account. Considering the importance of structural stability for forecasting accuracy in statistical modeling of time series, our estimation should be more robust than previous studies, as demonstrated by the comparison in subsection 5.3.3.

The reported results show that in the long run GDP *per capita* (with a preponderant role) and net foreign asset position (NFA) have a positive effect on equilibrium exchange rate, whereas the degree of openness (OPEN) has a negative one, implying that evaluating or even managing the long-run external value of RMB should be based on evolutions of these fundamentals. The departure of an actual real exchange rate from the estimated BEER would not be sustainable, as the cointegrating vector operates as an attractor that eventually brings the actual exchange rate back into line with the value consistent with the fundamentals, as highlighted by Clark and MacDonald (1998).[48] In the short-run, the real effective exchange rate of RMB is only influenced by *gdpp*, with a unidirectional effect as in the long-run. This

47. Within the more "flexible" exchange rate regime, the appreciations of RMB is driven by the expectation of further appreciation of RMB and subsequent inflow of hot money.

48. If this departure is because of excessive intervention in the foreign exchange market for one or another aims.

means that among these fundamentals only GDP *per capita* could be served as a short-run tool for adjusting the actual exchange rate of RMB.

Our results also show undervaluations of mild extent (at most 8 per cent) only during the recent period from 2003 to 2005, which are basically consistent with previous studies that focus on single-country estimation of equilibrium exchange rate of RMB, whereas studies estimating a group of countries by using the panel data reported greater undervaluations of RMB. One main possible explanation of this different degree of misalignment is the following: because of the heterogeneity of countries in the sample group, the "international standard", is obviously different from the "Chinese standard". In this circumstance, a BEER approach with "regional" panel data could be considered for future research, choosing a set of countries more or less homogeneous, for example, ASEAN or East Asia Summit member countries.

Finally, the hypothesis testing and estimations in this study are implemented in a specified VAR with one break in the constant, without supposing a second exogenous structural break, for example, the "global financial crisis" that originated from subprime crisis in 2007, because of the unavailability of data during this recent period. As mentioned in subsection 3.2, the stochastic components (coefficients of fundamentals) are the same in all subperiods, whereas only the vectors relating to the deterministic component could be different in each subperiod. Thus, once it is possible to include the new data, a model with two structural breaks could be estimated for further checking the robustness of our estimations. Furthermore, relative price of nontradable to tradable goods (TNT) could be used as an adequate proxy of Balassa-Samuelson effect for explaining the movements of equilibrium exchange rate of RMB, although in this article the inclusion of *tnt* do not allow specifying an appropriate model to estimate. If in China the price becomes further or even totally market-based and labor more mobile within the country, an estimation of equilibrium exchange rate with this variable will maybe provide interesting results.

J.C. [49]

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Appendix 1
Data

Quarterly CPI of China: Annual data (1978=100) are rebased with 2000 as the base year and then interpolated quarterly.[50] The obtained interpolated data of 2000 are taken as the *CPI* of base year, with which the quarterly *CPI* with (CPPY=100) are used to derive the final quarterly index with 2000 as the base year. Some authors obtain quarterly series by interpolating the yearly *CPI* extracted from database CEIC (Funke and Rahn, 2005).

Quarterly PPI of China: Taking 1995 as base year, we derive the fixed-base monthly *PPI* from monthly data (CPPY=100) that is then averaged to obtain the quarterly data, always with 1995 as the base year. Annual *PPI* series (1985-2005) are rebased with 1995 as the base year, and then linearly interpolated to obtain the quarterly series for 1994 and 1995. We combine the interpolated data (only for 1994 and 1995) and the averaged series (1996-2008), and rebase them to get the final quarterly series with 2000 as the base year.

EX(IM) of China: Annual *EX*(*IM*) with fixed base 2000 are derived from annual percentage change *EX*(*IM*) initially, and then interpolated for getting quarterly series.

50. The method of interpolation used in the paper is the linear one.

Table A1.1 - Data definitions and sources

Notation	Variables	Frequency[a]	Unit	Base Year	SA	Source
S	Bilateral exchange rate[b]	Q: P.A.	USD per National Currency	Current price	N	IMF, International Financial Statistics (IFS) country table
CPI	Consumer price index	Q	Index number	2005	N	IFS country table
	: Taiwan[c]	M	Index number	2006	SA	DGBAS, Datastream
	: China	Y: 1978-2005	Index number	1978	N	Database ChinaInfobank
		Q: 1994Q1-2008Q4	% change	CPPY[d]	N	IFS, China table
PPI	Producer price /Wholesale price index	Q	Index number	2005	N	IFS country table; OECD Main Economic Indicators[e]
	: Taiwan[c]	M	Index number	2006	SA	DGBAS, Datastream
	: China	Y: 1985-2005	Index number	1985	N	Database ChinaInfobank
		M: 1995M7-2008M12	Index number	Previous year	N	Datastream, China National Sources
EX	Export price index[f]	Q	Index number	2005	N	IFS, country table
	Taiwan[c]	M	Index number	2006	SA	DGBAS, Datastream
	China	Y	%YOY	Previous year	N	Economic Intelligence Unit, Datastream
IM	Import price index	Q	Index number	2005	N	IFS
	Taiwan[c]	M	Index number	2006	SA	DGBAS, Datastream
	China	Y	%YOY	Previous year	N	Economic Intelligence Unit, Datastream
EXP	EXPORTS, F.O.B.	Q	Millions USD	Current price	N	IFS, China table
IMP	IMPORTS, C.I.F.	Q	Millions USD	Current price	N	IFS, China table
GDP	Gross domestic product (GDP) China	Q: A	Hundred Millions Chinese Yuan	Current price	N	(National Bureau of Statistics of China, 2008) and National Bureau of Statistics of China database[g]
GDPpc	Real GDP *per capita* Purchasing Power Parity	Y[h]	2005 Constant USD	Constant price	.	Penn World Table Version 6.3, Heston *et al.* (2009)
Net foreign asset	Net external position	Y: 1980-2007[h]	Millions of USD	Current Price	.	Lane and Milesi-Feretti database: http://www.imf.org/external/pubs/cat/longres.cfm?sk=18942.0
Bilateral trade		Y	Ten thousands USD	1999-2001	N	China Statistical yearbook; Ministry of Commerce of China
Conversion rate of France, Germany, Italy and Netherlands			National currency per euro	.	.	European Central Bank: http://www.ecb.eu/press/pr/date/1998/ html/pr981231_2.en.html

[a] Y: Year; S: Semester; Q: Quarter; M: Month; P.A.: Period Average; P.E.: Period End; A: Accumulated.
[b] Quarterly data are averaged monthly exchange rates (National currency per USD) of Taiwan coming from DGBAS, Datastream.
[c] Monthly data are rebased (2000=100) and period averaged to get the quarterly ones.
[d] Corresponding period of previous year.
[e] PPI - Manufactured Products series for France, as PPI series in IFS is only available from 1999Q1.
[f] Export and Import price index for all sample countries except France, Hong Kong, Italy for whom their Export Unit Value/Export price are used, and China.
[g] Series of 1994Q1-2005Q4 and 2006Q1-2008Q4 come from these two sources respectively.
[h] Quarterly series are obtained by interpolation.

Appendix 2
LM two-break unit root test

The endogenous two-break LM unit root (Lee and Strazicich, 2003) can be described as follows. According to the LM (score) principle, a unit root test statistic can be obtained from the following regression:

$$\Delta y_t = d'\Delta Z_t + \phi \tilde{S}_{t-i} + \varepsilon_t \tag{19}$$

where $\tilde{S}_t$ is a de-trended series such that $\tilde{S}_t = y_t - \tilde{\Psi}_x - Z_t\tilde{\delta}$, $t = 2,\ldots,T$. $\tilde{\delta}$ is a vector of coefficients in the regression of Δy_t on ΔZ_t and $\tilde{\Psi}_x = y_1 - Z_1\tilde{\delta}$ where Z_t is defined below; y_1 and Z_1 are the first observations of y_t and Z_t, respectively, and Δ is the difference operator. ε is the contemporaneous error term and is assumed independent and identically distributed with zero mean and finite variance. $\Delta\tilde{S}_{t-i}$, $i = 1,\ldots,k$, terms are included as necessary to correct for serial correlation. Z_t is a vector of exogenous variables defined by the data generating process. Corresponding to the two-break equivalent of Perron's (1989) Model C, with two changes in level and trend, Z_t is described by $[1\ \ t\ D_{1t}\ D_{2t}\ DT^*_{1t}\ DT^*_{2t}]'$, where $D_{jt} = 1$ for $t \geq T_{Bj} + 1$, $j = 1, 2$, and zero otherwise, $DT^*_{jt} = t$ for $t \geq T_{Bj} + 1$, $j = 1, 2$, and zero otherwise, and T_{Bj} stands for the time period of the breaks. The test regression (1) involves ΔZ_t instead of Z_t so that ΔZ_t becomes $[1\ \ B_{1t}\ B_{2t}\ D_{1t}\ D_{2t}]'$, where $B_{jt} = \Delta D_{jt}$ and $D_{jt} = \Delta DT^*_{jt}$, $j = 1, 2$. The unit root null hypothesis is described in Eq.(19) by $\phi = 0$ and the test statistics are defined as follows:

$$\tilde{\rho} = \mathrm{T} \cdot \tilde{\phi} \tag{20}$$

$$\tilde{\tau} = t\text{-statistic for the null hypothesis } \phi = 0 \tag{21}$$

To endogenously determine the location of two breaks ($\lambda_j = T_{Bj}/T$, $j = 1, 2$), the minimum LM unit root test uses a grid search as follows:

$$LM_\rho = Inf_\lambda \tilde{\rho}(\lambda), \tag{22}$$

$$LM_\tau = Inf_\lambda \tilde{\tau}(\lambda). \tag{23}$$

Because results are similar, only the LM_τ test is used here. As shown in Lee and Strazicich (2003), critical values for Model C depend (somewhat) on the location of breaks (λ_j). Therefore, we utilize critical values that correspond to the location of the breaks. To implement this test, one needs to determine the number of augmentation terms $\Delta\tilde{S}_{t-i}$, $i = 1,\ldots,k$, which correct for serial correlation in Eq.(19). At each combination of break points $\lambda = (\lambda_1,\lambda_2)'$ in the time interval $[0.1T, 0.9T]$ (to eliminate end points), where T is the sample size, k is determined by following a "general to specific" procedure described in Perron (1989). Starting from a maximum of $k = 8$ lagged terms, the procedure looks for significance of the last first-differenced lagged term. Compared with the 10 percent asymptotic normal value of 1.645, if the t-statistic of this lagged term is insignificant, the maximum lagged term is dropped and the model re-estimated with $k = 7$ terms, until either the maximum term is found or $k = 0$, at which point the procedure stops. After determining the optimal at each combination of two breakpoints, the breakpoints are determined to be where the test statistic is minimized.

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