Just How Undervalued is the Chinese Renminbi?

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ABSTRACT

Given that the value of China's currency has been hot topic recently, this paper explores the equilibrium levels of China's real and nominal exchange rates. Employing a Johansen cointegration framework, we focus on the behavioral equilibrium exchange rate (BEER) and permanent equilibrium exchange rate (PEER) models. Our results suggest that, while the renminbi is somewhat undervalued against the dollar, the misalignment is not nearly as exaggerated as many popular claims.

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1. INTRODUCTION

Misalignment in the Chinese currency, the renminbi, has been the focus of much recent interest. Since it was devalued in 1994, China's currency has been kept at a constant nominal level to the US dollar despite China's rapid economic growth, rising productivity, vibrant exports, and massive foreign direct investment inflows – all factors that normally cause a currency to appreciate.[1] Moreover, the resulting build-up of central bank foreign reserves in itself is sufficient to justify renminbi appreciation.

The US government complains vociferously that an undervalued renminbi is keeping China's exports artificially cheap and causing job losses in America, Japan, and other Asian economies. Given China's strength as a trading nation, the fear is that China has achieved exuberant growth by selling deliberately undervalued exports and transforming itself into the "workshop of the world."[2] With seemingly infinite pools of underemployed workers in the countryside and in inefficient state-owned enterprises, as well as pitifully low wages, China looks like it should be able to out-compete other economies in almost any category of manufacturing with significant labor inputs. The response of politicians in America and elsewhere to this perceived threat has been to lobby for a change in China's exchange rate regime and an end to Chinese "currency manipulation".[3] Despite the perverse impacts of the dollar peg on international adjustment processes, the complaints from Europe have been more modest than those from America.[4] Finally, other Asian countries are worried that China is hogging the region's foreign direct investment inflows.

If one concludes a currency is misaligned, the next issue is to determine by how much. On this point, substantial disagreements rage over how undervalued the renminbi might be. Estimates vary wildly.[5] According to the "Big Mac index", a familiar, light-hearted indicator of whether world currencies are

[1] China's currency is generally known as the renminbi, but the unit of measurement is the yuan (terminology that parallels "sterling" and "pound" in the UK).

[2] China's merchandise exports increased from about US$10 billion per annum in the late 1970s to US$326 billion in 2002, or about 5 percent of total world exports – making it the sixth largest trading nation in the world. This article is not intended to be a comprehensive review of this debate. For a brief summary, see "China is Becoming the World's Manufacturing Powerhouse," World Bank, *Transition Newsletter About Reforming Economies*, available at http://www.worldbank.org/transitionnewsletter/octnovdec02/pgs4-6.htm.

[3] Unfortunately, tensions are rising. The debate has become highly politicised since the American government has tried to commit Beijing to scrap its misaligned 8.277 de facto peg with the US dollar (for further details, see http://www.ustreas.gov/press/releases/js956.htm).

[4] When the dollar depreciates, the renminbi depreciates along with it. China's international competitive position thus strengthens and its current account surplus rises, placing additional pressure on America's other trading partners to accommodate the needed reduction in the US current account deficit.

[5] Other papers that address China's real exchange rate notably include Chou and Shih (1998) and Zhang (2001a). Chou and Shih investigate movements of the purchasing power parity exchange rate. They conclude that the renminbi was about 10 percent undervalued at the beginning of the 1990s. Zhang (2001a) has estimated a bilateral US dollar/renminbi behavioral equilibrium exchange rate model and a structural time series model (unobserved component model) for the period 1952 to 1997 using annual data. His econometric analysis reveals that the actual renminbi exchange rate fluctuated closely around the equilibrium exchange rate, and was close to equilibrium in 1997. In contrast, Preeg (2003) has recently estimated that unfair Chinese currency manipulation has resulted in a renminbi exchange rate undervaluation of about 40 percent.

at their "correct" level, the renminbi was determined to be 56 percent undervalued as of April 2003.[6] In other words, a good dose of appreciation was justifiable.[7] The *Economist* recently responded with its own "Starbucks tall latte index" and reached similar conclusions.[8] While the Starbucks tall latte index tells broadly the same story as the Big Mac index for most currencies, the two measures differ widely in Asia. According to the Starbucks tall latte index, the renminbi was only 1 percent undervalued as of January 2004, implying that China has been unfairly accused of undervaluing its currency.

Obviously, "burgernomics" and "lattenomics" are both distorted – they consider a single good. A wiser, less fanciful, approach is to look at the deviations from purchasing power parity (PPP) for a broad basket of goods. The most reliable PPP data are available from the International Comparison Program (*ICP*). Figure 1 shows the *ICP*-based PPP conversion factor divided by the nominal exchange rate. The ratio makes it possible to compare the cost of the bundle of goods that make up *GDP* across countries. If the ratio is greater (smaller) than one, it is overvalued (undervalued). If it equals one, then the currency is at the proper level according to PPP. From this, we can see that the renminbi was at 0.23 in 2001. The obvious implication is that the renminbi is super-competitive. But how meaningful is this extreme result? Figure 2 presents a scatter plot of 135 nations around the world for 2001. The vertical axis shows the PPP conversion factor divided by the exchange rate and the horizontal axis shows PPP converted to per capita gross national income (*GNI*). China, Hong Kong and the US are marked with arrows.

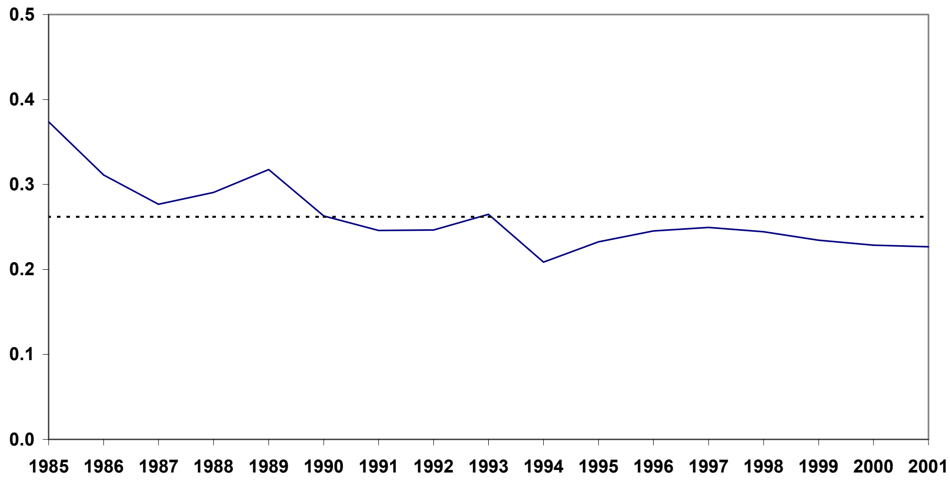
Note that in developing countries, where per capita incomes are relatively low, currencies are typically undervalued. Once this is taken into account, the degree of undervaluation shrinks, i.e. the PPP conversion factor to nominal exchange rate ratio does not have to reach one. If we take the average ratio over the period 1985–2001 as a baseline (see dotted line in Figure 1), then the degree of undervaluation drops significantly.

[6] The Big Mac "basket" consists of one McDonald's Big Mac hamburger, which is produced in 110 countries. The Big Mac PPP is the exchange rate that would result in hamburgers costing the same in the US as abroad. Comparing actual rates with PPPs signals whether a currency is under- or overvalued (for more details on the index and ten years of findings, see http://www.economist.com/markets/Bigmac/Index.cfm). Academics have taken burgernomics seriously in recent years, applying the Big Mac index in nearly a dozen studies [e.g. Cumby (1996), Ong (1997), Ong (2003), Pakko (1996), and Parsley and Wei (2003)]. These studies generally find the Big Mac is surprisingly accurate in tracking exchange rates over the long run.

[7] Such undervaluation is not abnormal, and in fact common, among developing countries. The estimated undervaluation for the currencies of Russia, Brazil, and Indonesia, for example, was 51 percent, 45 percent and 32 percent, respectively.

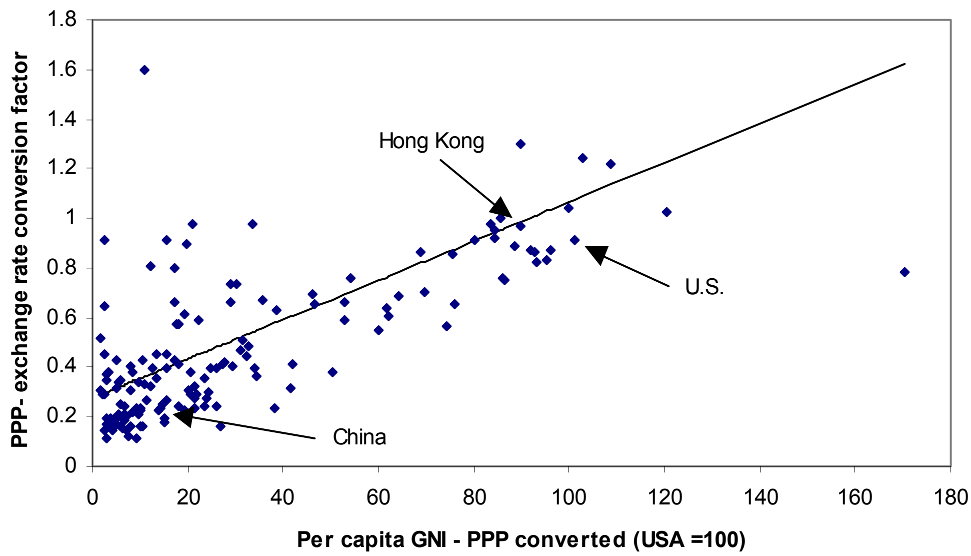
[8] See the *Economist*, 17 January, 2004, p. 63.

Figure 1: Renminbi PPP Conversion Factor to Nominal Exchange Rate Ratio, 1985–2001



Source: *World Development Indicators 2003* (CD-ROM).

Figure 2: PPP Conversion Factor to Exchange Rate Ratio Versus PPP Per Capita GNI in 2001



Notes: PPP per capita GNI is per capita gross national income converted to international dollars. Source: *World Development Indicators 2003* (CD-ROM).

In an article published in the *Financial Times* (26 August, 2003) and the *Asian Wall Street Journal* (12 September, 2003), Morris Goldstein and Nicholas Lardy consider the misalignment of the renminbi. Their appraisal found that the renminbi was undervalued 15–25 percent against the dollar.[9] Recently, Fred Bergsten (2004) has suggested a single step revaluation of the renminbi by 20-25 percent.

[9] See http://www.iie.com/publications/papers/goldstein0803.htm.

Against these diverse assessments, we now attempt to derive the equilibrium exchange rate of the renminbi to gauge for ourselves the degree of misalignment. The necessary steps in calculating the equilibrium exchange rates are sketched in Section 2. Section 3 describes in detail the data used in the empirical analysis. The estimation results are presented in section 4. Finally, in Section 5, we summarise the results and conclude. We also include an appendix that describes the derivation of estimates for bilateral nominal equilibrium exchange rates.

2. ALTERNATIVE APPROACHES TO CALCULATING EQUILIBRIUM EXCHANGE RATES

Rather than using PPP exchange rates, we focus on the behavioural equilibrium exchange rate (BEER) and the permanent equilibrium exchange rate (PEER) models, which make identification of equilibrium exchange rates more rigorous.[10] Equilibrium exchange rates can be thought of as an attractor for the actual exchange rate, pulling the actual exchange rate toward it.

a. Behavioural Equilibrium Exchange Rate

A behavioural equilibrium exchange rate involves reduced-form modeling of the exchange rate with standard cointegration techniques. The fundamentals driving the exchange rate are typically the economic factors determining internal and external equilibrium. However, the BEER does not guarantee the equilibrium. Any equilibrium exchange determined by internal and external equilibrium would necessarily involve a judgment about the sustainability of the current account rate and thus impose a normative constraint. The BEER is the data-determined systematic component of the exchange rate in the medium and long run.[11] Consider the real exchange equation

$$q_t = \delta_0 + \delta_1 z_t + \varepsilon_t \,, \tag{1}$$

[10] The approaches do not differ so much in theory, but rather in the techniques they use to implement the underlying theory.

[11] There is a range of alternative approaches available to estimate equilibrium exchange rates such as BEER, DEER, FEER, PEER, and NATREX. Our focus on the BEER and PEER approach reflects the fact that both measures do not require normative assumptions regarding sustainability of current account balances or trade elasticities. On the contrary, the resulting equilibrium exchange rates are entirely data determined without any arbitrary judgment involved. An in-depth discussion of both approaches is available in Clark and MacDonald (1999, 2000). Williamson (1994) proposed the Fundamental Equilibrium Exchange Rate (FEER) approach, while Stein (1994) developed the Natural Real Exchange Rate (NATREX) model. The IMF defines its DEER as essentially FEER based on an optimal fiscal policy trajectory. These approaches have been applied in a variety of contexts. See Égert (2004) for an overview about the EU accession countries and http://www.ssc.wisc.edu/~mchinn/euro_papers.html for a list of applications to the euro.

where z_t is a vector of economic fundamentals that affect the real exchange rate (q_t) in the medium or long run. Any deviation from equilibrium is reflected in the error term (ε_t), which includes both short-term influences and random disturbances. The equilibrium real exchange rate ($\overline{q}_t$) is thus defined as

$$\overline{q}_t = \delta_0 + \delta_1 z_t . \tag{2}$$

The choice of economic fundamentals varies among studies. We refer here to the popular theoretical model advanced by Faruqee (1995) and extended by Alberola et al. (1999), Hansen and Roeger (2001), and Lorenzen and Thygesen (2002). In this model, the systematic component of the exchange rate is driven by the productivity differential between the home country and abroad (*PROD*), the net foreign asset position (*NFA*) and demand factors. Since demand factors are difficult to measure, they are commonly ignored in empirical studies. We obtain the variable space

$$\overline{q}_t = f(PROD_t, NFA_t), \tag{3}$$

which motivates the empirical work. The impact of productivity differentials on the real exchange rate is commonly known as the Harrod-Balassa-Samuelson effect, whereby one country's relatively higher productivity increases are associated with a real appreciation of its currency.[12]

The net foreign asset position affects the real exchange rate through several channels. For instance, a worsening of the net foreign position means higher interest payments for net debtor countries on their debt and smaller incomes from interest payments for creditor countries. These shifts must be financed by an improvement in the trade balance, which requires a depreciation of the currency. Higher debt also leads to a rise in the risk premium. At some point, however, a higher yield can only be guaranteed if the domestic currency depreciates.[13] The exact definitions of the variables entering (3) are described in detail in the next section.

Here, our econometric methodology for applying the BEER approach is the multivariate cointegration technique as suggested by Johansen (1995). Its starting point is a vector-error correction model (VECM)

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[12] The Harrod-Balassa-Samuelson effect is highly relevant to the Chinese economy, which is characterized by rapid growth that is presumably due to rapid manufacturing (and hence, traded) sector productivity growth. For a comprehensive overview of the theoretical contributions and the empirical evidence for the existence of a Harrod-Balassa-Samuelson effect, see Sarno and Taylor (2002), pp. 79-82. Chinn (2000) has confirmed empirically that developments in relative productivity can account for exchange rate developments in Asia.

[13] Researchers have generally argued that a strong long-run relationship exists between persistent deficits (surpluses) in the current account balance and the depreciation (appreciation) of the real exchange rate [see e.g. Obstfeld and Rogoff (1995)]. Faruqee (1995) has motivated the NFA variable from a stock-flow model of the exchange rate.

$$\Delta x_t = \eta + \sum_{i=1}^{p-1} \Phi_i \Delta x_{t-i} + \Pi x_{t-1} + \varepsilon_t , \qquad (4)$$

where the (3×1) vector $x_t = [RER_t, PROD_t, NFA_t]'$. In the equation, η is a (3x1) vector of constants, Δ is the first difference operator, ε represents a (3×1) Gaussian vector error process, Φ denotes a $(3\times(p-1)$ matrix of short-run coefficients and Π is a (3×3) coefficient matrix. If Π has reduced rank $r < 3$, then there exist two $(3\times r)$ matrices α and β, such that $\Pi = \alpha\beta'$, where α is interpreted as the adjustment matrix and the columns of β are the linearly independent cointegrating vectors of the VECM. These cointegrating vectors determine the BEER.

b. Permanent Equilibrium Exchange Rate

The BEER approach suffers from the drawback that variables entering the calculations are not themselves at what are deemed to be the equilibrium values. One way to measure equilibrium exchange rates is to remove the business cycle from the data using a Hodrick-Prescott or bandpass filter. Alternatively, we can decompose the time series into permanent and transitory components. The transitory component is characterized as having limited memory, while the permanent component is expected to have a persistent impact. The permanent component is then interpreted as a measure of equilibrium and forms the Permanent Equilibrium Exchange Rate (PEER). Several authors suggest procedures for decomposing time series [e.g. Cumby and Huizinga (1990), Clarida and Gali (1994)]. Here, however, we use a procedure from Gonzalo and Granger (1995), which explicitly considers the cointegration relationships among the variables and provides a direct link to the BEER approach.[14]

The permanent component of a series is typically associated with a non-stationary, i.e. an I(1), process, while the transitory component is stationary or I(0). Gonzalo and Granger (1995) demonstrate that the results from the VECM can be used to identify both components. If the time series are cointegrated, the matrix Π has a reduced rank $r < n$ and there are $n - r$ common factors (f_t). With the assumptions that the common factors are linear combinations of the variables and that the temporary component does not Granger-cause the permanent component, the common factors may be given as

$$f_t = \alpha_\perp x_t . \qquad (5)$$

[14] The PEER approach has typically been applied to western industrialised countries. Clark and MacDonald (2000) focus on the exchange rates of the United States, Canada, and the United Kingdom. Alberola et al. (1999) use a sample of various industrialised economies, including several western European countries. Maesco-Fernandez et al. (2001) focus on the euro-dollar exchange rate.

This identification of the common factors makes it possible to decompose the time series $x_t = [RER_t, PROD_t, NFA_t]'$ into permanent $x_t^P = \left[\mathrm{RER}_t^{\mathrm{perm}}, \mathrm{Prod}_t^{\mathrm{perm}}, \mathrm{NFA}_t^{\mathrm{perm}}\right]'$ and transitory $x_t^T = \left[\mathrm{RER}_t^{\mathrm{trans}}, \mathrm{Prod}_t^{\mathrm{trans}}, \mathrm{NFA}_t^{\mathrm{trans}}\right]'$ components according to

$$\bar{x}_t^P = A_1 \alpha'_\perp x_t = \beta_\perp (\alpha'_\perp \beta_\perp)^{-1} \alpha'_\perp x_t \,, \tag{6}$$

and

$$\bar{x}_t^T = A_2 \beta' x_t = \alpha(\beta'\alpha)^{-1} \beta' x_t \,. \tag{7}$$

where $\alpha_\perp$ and $\beta_\perp$ denote the orthogonal complements to α and β (that is, $\alpha'\alpha_\perp = 0$ and $\beta'\beta_\perp = 0$) and $\alpha_\perp$ determines the vectors defining the space of the common stochastic trends and thus identify the underlying driving forces, while $\beta_\perp$ gives the loadings associated with $\alpha_\perp$, i.e. those variables driven by common trends.

Another source of information is the moving average representation of the VECM as proposed by Johansen (1995)

$$x_t = C \sum_{i=1}^{t} \varepsilon_t + C\eta + C(L)(\varepsilon_t + \eta) \,, \tag{8}$$

where

$$C = \beta_\perp (\alpha'_\perp (I - \sum_{i=1}^{k-1} \Phi_i) \beta_\perp)^{-1} \alpha'_\perp \,. \tag{9}$$

The C-matrix thus measures the combined effects of both orthogonal permanent components described above.

3. DATA AND (NOT-SO-TRIVIAL) MEASUREMENT ISSUES

It is helpful here to briefly sketch the data. Quarterly data are used for all time series. For the calculation of real effective rates, we use data from China's three largest trading partners: Japan, the US, and the euro zone (Euroland). Most data are obtained from the International Financial Statistics

(*IFS*) database; other sources are cited in the text. The length of the time series is limited by data availability for China and covers the period from 1985:1 to 2002:4 for all countries. The variables used in the empirical analysis encompass real effective exchange rates, productivity levels, and the net foreign asset position.

a. Real Effective Exchange Rate

Exchange rates are defined as the log of a CPI-deflated index, where an increase reflects an appreciation for the home country's currency. For the effective rate, the weighted average is here taken over the bilateral trade volumes of mainland China against Japan, the US, and Euroland. Trade with these economies in 1996 amounted to 47 percent of mainland China's total trade. These trade weights are based on cumulated export and import volumes, where exports have been double weighted to account for third-market effects. Table 1 presents the resulting trade matrix with trade weights normalized so that they add up to one.

Table 1: Trade Matrix

	China	U.S.	Japan	Euroland
China	0.00	0.33	0.44	0.23
United States	0.12	0.00	0.41	0.47
Japan	0.16	0.58	0.00	0.26
Euroland	0.11	0.64	0.25	0.00

Note: The numbers are calculated from 1996 *International Trade Statistics Yearbook* data.

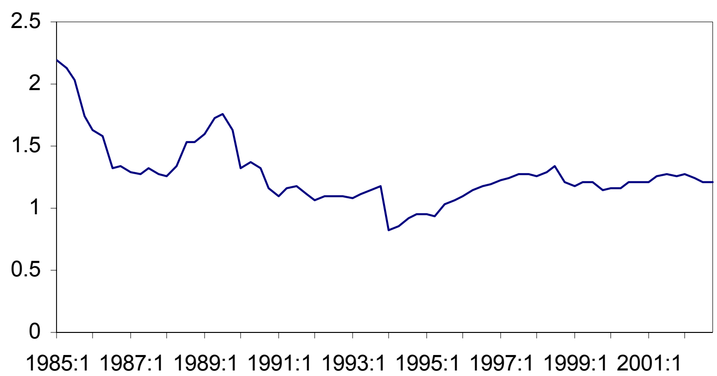
The log real effective exchange rate for country i (q_i) is thus the trade-weighted average of the log bilateral real exchange (e_{ij}) rates vis-á-vis its trading partners:

$$q_i = \sum_j w_{ij}\ e_{ij}\ , \tag{10}$$

where the trade weights w_{ij} sum up to one, i.e. $\sum_j w_{ij} = 1$. All exchange rates are average values for the period. Although figures for the euro do not exist prior to its introduction in 1999, the ECB has published a "synthetic" value for the nominal euro/dollar exchange rate preceding the euro's introduction. It is based on the real exchange rates of the twelve participating countries with each country weighted by its share of manufacturing trade of the euro area. Figure 3 displays the resulting real effective exchange rate of China from 1985:1 to 2002:4.

Between 1981 and 1986 the renminbi was pegged to a basket of internationally traded currencies weighted according to their importance in China's trade. From 1986 to 1994, a managed-float, multiple-exchange-rate regime was used.[15] An "official" rate (a peg to the US dollar that was adjusted several times), an "unofficial" floating rate (a swap market rate that the central bank occasionally adjusted through market intervention) and an "effective" exchange rate actually faced by exporters (the weighted average of the "official" and "unofficial" rate) were introduced to offset the disincentives to export arising from the overvalued official exchange rate. From 1989, the Chinese authorities repeatedly devalued the official rate, eventually unifying the "official" and "unofficial" exchange rates at the prevailing rate in 1994.[16] This devaluation explains the sharp drop of the real effective exchange rate at the beginning of 1994. On a real basis, the trade-weighted renminbi then appreciated sharply through 1999, because China's inflation rate exceeded that abroad. During the Asian crisis in 1997/98, with the renminbi being held stable against the US dollar, China's real effective exchange rate appreciated further, mostly on account of the appreciation of the yen against the US dollar. Thereafter, this latter appreciation was reversed as the yen rebounded and China's inflation rate fell and turned negative. In 2002, the index for the real exchange rate is roughly at the same level as in 1997.

Figure 3: China's Real Effective Exchange Rate, 1985:1–2002:4



To cross-check the results, we compare the calculated real effective exchange rate against the real effective exchange rate for China available in the *World Development Indicators 2003*. These figures match well; the correlation coefficient turns out to be 0.902 over the sample period 1985–2001.[17] This outcome serves to improve our confidence that the real effective exchange rate measure used is plausible.

[15] See Mehran et al. (1996) for further details. A brief description of historical Chinese exchange rate regimes is available at http://intl.econ.cuhk.edu.hk/exchange_rate_regime/index.php?cid=8.

[16] The deleterious effects of multiple exchange rates (corruption, resource misallocation, rent seeking, etc.) are well documented. China's exchange rate regime choices during transition are analysed in Zhang (2001b).

[17] Note that the annual frequency of the *WDI* data requires us to compact our series. We have used the simple average as the form of compaction.

b. Productivity Levels

The next step is to calculate proxies for the Harrod-Balassa-Samuelson effect. Following common practice, we take the trade-weighted average of the ratio of the local consumer price to the wholesale price as an empirical counterpart to the theoretical variable. This measure is necessarily a compromise, reflecting the fact that any "right measure" is unobservable due to limited data availability.[18]

This measure retains prices of the non-traded services in the numerator (but not in the denominator). The studies by de Gregory et al. (1994) and Canzoneri et al. (1999) testify to a close link between sectoral productivity and sectoral prices in developed countries. We take the log of the ratio of the domestic consumer price index to the domestic producer price index relative to the corresponding foreign ratio using the same trade weights as above, i.e.

$$\Pr od_{i,t} = \log\left(\frac{CPI_{i,t} / WPI_{i,t}}{\prod_{\forall j \neq i} (CPI_{j,t} / WPI_{j,t})^{w_j}} \right). \tag{11}$$

Chinese data for consumer price index are available on a quarterly basis beginning in 1987 from the *IFS* database. Annual data from the *CEIC* database are used to extend the time series back to 1985. The same data source also publishes annual *PPI* values for China, which we transform from low frequency (annual data) to high frequency (quarterly data) using an optimal interpolation procedure.[19]

For the euro area, the synthetic value for the period prior the introduction of the euro, i.e. up to 1998:4, is computed. This value is based on the price indices of the twelve participating countries with each country weighted by the share of trade with economies outside the European Union.

It may be claimed that the proxy variable in (11) is also affected by non-productivity factors. Accordingly, we have cross-checked the reliability of the data by comparing our proxy variable (11) against the direct relative labour productivity ratio of mainland China to the weighted average of Euroland, Japan, and the US. The results in Figure 4 indicate that both series match very well; the correlation coefficient turns out to be 0.973 over the sample period 1985–1999.[20] We may thus conclude that the $Prod_{it}$ variable is indeed plausible.

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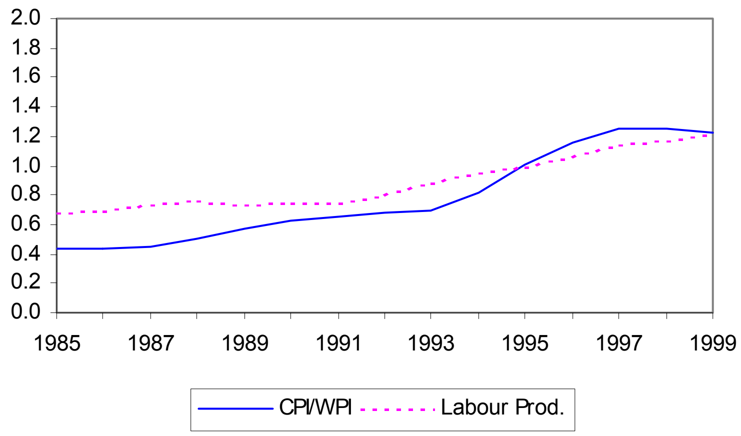
[18] Examples for the application of this proxy are given in Alberola et al. (1999), Chinn (1999), Clark and MacDonald (1998, 2000), Kakkar and Ogaki (1999) and Rahn (2003).

[19] Very briefly, the quarterly data are derived by solving a quadratic optimization problem. For details on the dynamic programming algorithm, see Bertsekas (1976), pp. 70-72. Keep in mind that interpolated data are no substitute for actual data, since the higher resolution is fictitious. However, interpolation is very useful when most of the data in a multivariate analysis are at a higher frequency and one would have to compact all of those to use them together with a few low-frequency series.

[20] Note that the annual frequency of the labour productivity data requires us to compact our series. We have used the simple average as the form of compaction. When calculating the relative productivity index, we have used the same trade weights as above.

Figure 4: Relative Labour Productivity Index and the Relative CPI/PPI Price Ratio



Note: The numbers for China are obtained from the *CEIC Database* (see http://www.ceicdata.com/econ/; the labour productivity series is only available until 1999). The numbers for the main trading partners come from the OECD database.

c. Net Foreign Asset Position

Direct figures on net foreign assets are unavailable for all countries and all time periods. Thus, we follow the alternative method suggested by Lane and Milesi-Ferretti (2001), whereby we take an initial value of the stock of net foreign assets and add up current account balances to determine the time series. Unfortunately, not even an initial stock is available in the case of China. Thus, current account balances are added up historically, starting in 1982. Chinese current account data is only available on an annual basis, so quarterly data must be generated using the same procedure as above. For Europe, consolidated data from the *ECB* are available back to 1997. For earlier periods, figures on current account data of all twelve-member countries are summed. The calculated net foreign assets time series are then seasonally adjusted using the additive *X-12* method, wherever tests suggest seasonality. They are normalized by nominal *GDP* (in US dollars) to adjust for the size of each country.[21]

4. EMPIRICAL RESULTS

Before proceeding with the estimation, it is necessary to test for the degree of integration of the individual time series. The visual inspection of the real exchange rate in the previous chapter observation revealed possible break points in the real exchange rate time series. Thus, instead of conventional Augmented-Dickey-Fuller (ADF) tests, we use the Unit-Root Test suggested by Perron (1997). This test has the advantage of allowing for a structural break in the time series. Moreover, the

[21] *IFS* data on nominal *GDP* for China have only been published since 1999. For the period from 1985 to 1998, annual data from the *CEIC* had to be transformed to quarterly data using the same methodology as above.

timing of the breakpoint is determined endogenously, so that our visual observation can be cross-checked. Table 2 shows the unit root tests of all three-time series as well as the corresponding break points. In all three cases the null hypothesis of a unit root cannot be rejected. But what is more important, there is strong evidence for a break in the exchange rate and the productivity time series at the turn of the year from 1993 to 1994.

Table 2: Unit-Root Tests with Endogenous Breakpoints (Perron, 1997)

Variable	Test Statistic	Break Date
Real exchange rate (*RER*)	-4.84 (4)	1993:4
Productivity differential (*PROD*)	-4.05 (3)	1994:1
Net foreign asset position (*NFA*)	-3.28 (3)	1993:1

Note: 5 % Critical Value: -5.59; 1 % Critical Value: -6.32. The number of optimal lags is given in parenthesis.

One reason for the common finding of a unit root in macroeconomic variables is the low power of unit root and cointegration tests when the variables follow a nonlinear process. For example, it is well known that the power of standard unit root and cointegration tests falls sharply when the true model is a threshold process [see, for example, Pippenger and Goering (1993, 2000)]. We, therefore, additionally employ Hansen's (2000) threshold estimation procedure, which provides an intuitive and simple setting for testing for linearity. The approach is based on a very simple idea. The model takes the form

$$y_t = \alpha + \beta'_1 x_t I\left(q_t \le \gamma\right) + \beta'_2 x_t I\left(q_t > \gamma\right) + e_t, \tag{12}$$

where y_t is the dependent variable, x_t is a vector of regressors, $I(\cdot)$ is an indicator function, q_t is the threshold variable, and e_t is an iid $N(0, \sigma^2)$ error term. Equation (12) can be re-written as

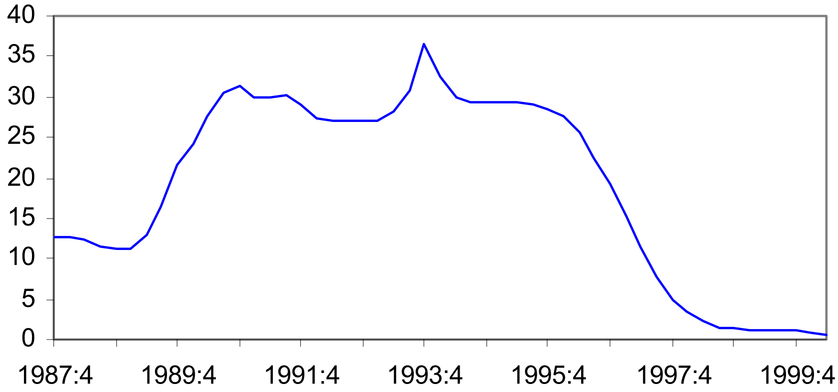
$$y_t = \begin{cases} \alpha + \beta'_1 x_t + e_t & \text{if} \quad q_t \le \gamma \\ \alpha + \beta'_2 x_t + e_t & \text{if} \quad q_t > \gamma \end{cases}. \tag{13}$$

The threshold model therefore allows the regression parameters to differ depending on the value of q_t. The specification collapses to the traditional linear one if $\beta_1 = \beta_2$. Hansen (2000) suggests a practical, straightforward method for estimating γ using least-squares techniques and to construct asymptotically valid confidence intervals for γ.[22] *F*-tests can then be used to test for threshold effects ($\beta_1 \ne \beta_2$). In other words, the procedure allows testing for whether the identified threshold effect is statistically

[22] The computationally simple procedure determines γ as the value that minimizes the concentrated sum of squared errors function.

significant. Figure 5 shows the F-test sequence for the linear exchange rate equation $q_t = \alpha + \beta_1 PROD_t + \beta_2 NFA_t + e_t$, when time is used as the threshold variable.

Figure 5: *F*-Test Sequence for the Threshold Model



Note: In principle, the idea would be to test for $\beta_t^1 = \beta_t^2\ \forall t$. However, this simple testing problem presents an extra difficulty: the threshold parameter, γ, is only identified under the alternative hypothesis of nonlinearity. The lack of identification of γ under the null hypothesis distorts the distribution of the test statistic. Hansen (2000) overcomes the problem with a bootstrapping procedure. Taking the estimated linear relationship, artificial data on the dependent variable are simulated and both a linear and a piecewise linear model are estimated. The corresponding test statistic is computed and the procedure is repeated many times, leading to an approximate distribution of the test statistic under the null of linearity. Using this procedure with 1,000 replications yields the p-value of the structural break at 1993:4 (p = 0.000).

The F-sequence displays significant structural instability at 1993:4. This would suggest to subdivide the sample and to estimate the cointegration relationship over the subsample from 1994:1 to 2002:4. A potential problem with the decision to ignore data before 1994 is that the break in the data is timed to coincide with the unification of the exchange rate system that was accompanied by a devaluation. In other words, the analysis may be biased by an "initial point" issue. On the other hand, a familiar criticism of long-span exchange rate studies is that, because of the long data spans involved, various exchange rate regimes are often spanned. In any case, it seems prudent to test whether a cointegrating relationship exists over the whole sample period. The obvious problem is that parameter nonconstancy may have severe consequences and inferences may be misleading. Therefore, care needs to be exercised when testing for cointegration over the whole sample period.

Hansen (1992b) has suggested a single-equation cointegration test that has specifically been designed for $I(1)$ regressions with (potential) parameter instability. The test is based upon the asymptotically efficient fully modified estimator (FM-OLS) and does not depend on an *a priori* assumption of a specific break date. The test statistic, Lc, is a test for cointegration with the null hypothesis that the variables are cointegrated. Thus, Lc can be regarded as a complementary test of the Johansen test in the sense that it reverses the null hypothesis with the alternative hypothesis of the latter.[23] To cross-check the threshold results in Figure 4, we have calculated the *Lc* statistic over the sample period 1986:1 – 2002:4. The *Lc* statistic turns out to be 16.38 (p-value = 0.000).[24] Judged on the basis of inference, the estimation results therefore lend support to the finding that the null of cointegration over the whole sample period can be rejected. Since the whole sample period covers both pre- and post-reform years, one does not wonder that factors associated with the reform, like a change in monetarisation, a change in the economic straucture, etc., have had an impact.

Given this result, we proceed to subdivide the sample. Thus, we now concentrate on the time period from 1994:1, the first period after the devaluation of the renminbi, until the end of the sample, 2002:4. As this has no implications on the time series properties, we can now test for cointegration between the variables.[25] We use the maximum-likelihood methods of Johansen (1995) both to determine the existence of cointegration and to produce estimates of the BEER and PEER. The test statistics are summarized in Table 3. A warning is appropriate here. We use small samples in our empirical application, and there is evidence that small samples may cause spurious rejection of the null hypothesis of no cointegration. One recommended solution to this problem is to adjust the values of the statistics to take into account the small sample size. We have thus used the more restrictive procedure suggested by Reimers (1992), which corrects the trace test for degrees of freedom. Overall, the results suggest that it is reasonable to assume a single cointegration relationship between the variables of interest.

Table 3: Cointegration Tests, 1994:1–2002:4

Null-Hypothesis	Eigen-value	Trace Statistic: Statistic	Trace Statistic: 5% Critical Value	Trace Statistic: 1% Critical Value
At Most 1	0.87	87.24	29.68	35.65
At Most 2	0.28	15.13	15.41	20.04
At Most 3	0.10	3.58	3.76	6.65

Note: The lag length has been chosen in order to minimize the Akaike and Schwarz criteria. The small sample correction suggested by Reimers (1992) uses (T-np), rather than T, as a scaling factor.

Moving to the estimation of the cointegration relationship, Table 4 presents the normalized cointegrating vector (β), as well as the corresponding adjustment coefficients. As theory suggests, the

[23] We are using the *Lc* statistic because Monte Carlo experiments reveal loss of power and size distortions for conventional methods in the presence of structural breaks. The obvious reason is that conventional tests are mis-specified under the alternative hypothesis when the true data generating process is characterised by structural breaks.

[24] The appropriate p-values are obtained from Hansen (1992b), p. 328. Over the sample period from 1986:1 to 1993:4 the test statistic even turns out to be $Lc = 235.64$ ($p = 0.000$).

[25] The results from Perron (1997) unit root tests for the restricted time period from 1994:1 to 2002:4 are as follows: real exchange rate, -4.31 (4); productivity differential, -3.04 (1); and net foreign asset position, -4.87 (4).

productivity differential and net foreign asset position have a positive and significant impact on the effective real exchange. The magnitude of the calculated numbers is well in line with results from studies on OECD countries [e.g. Alberola et al. (1999) and Clark and MacDonald (2000)], which find productivity coefficients between 0.60 and 2.00 and net foreign asset coefficients between 0.01 and 1.00. The significantly negative α coefficient indicates that the real exchange rate adjusts significantly negatively to the disequilibrium exchange rate error.

Table 4: Normalized Cointegration Vector and Weak Exogeneity Tests

	Real Exchange Rate	Productivity Differential	Net Foreign Asset Position
β	1	-0.77	-0.10
(t-value)		(-14.08)	(-2.46)
α	-0.47	0.12	0.05
(t-value)	(-8.69)	(2.23)	(3.70)

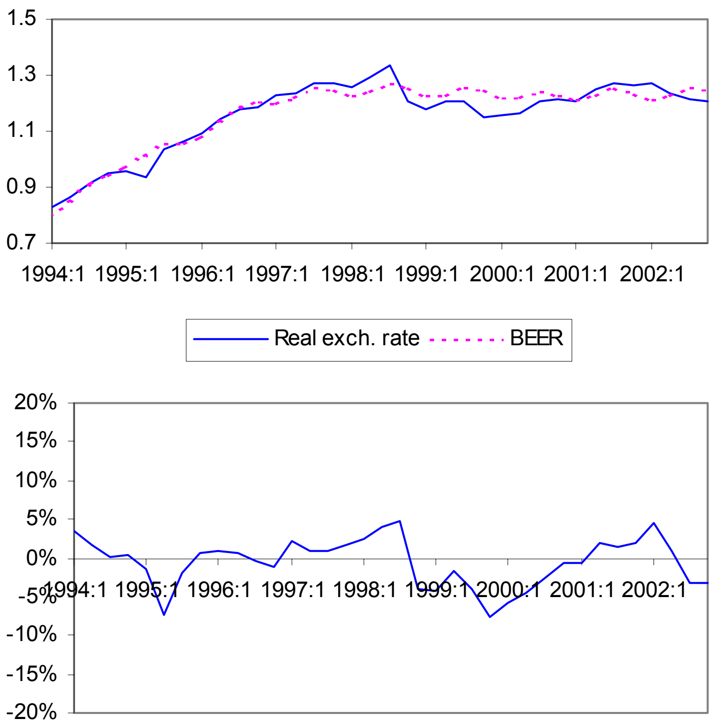
As possible breakpoints appeared in the regression analysis, we perform Hansen's (1992a) Lagrange-multiplier-type tests to check for possible parameter instability. The LM-type test statistics test the null hypotheses of parameter and variance constancy in static and dynamic regression equations, i.e. no special treatment of lagged dependent variables is required. They are based upon an average of the squared cumulative sums of first-order conditions. Under the null hypothesis of parameter stability, the first-order conditions are mean zero, and their cumulative sums wander around zero. Under the alternative hypothesis of parameter instability, the cumulative sums develop a nonzero mean in parts of the sample and therefore the test statistics tend to be large. The alternative includes simple structural breaks of unknown timing, as well as random walk parameters. An advantage of these tests is that they only require a single estimation of ECMs over the full sample, i.e. no sample-split points need to be chosen. They are useful, however, for determining the timing of a structural break, if one has occurred.

Table 5: Parameter and Variance Stability Tests in the VECM, 1994:1–2002:4

Dependent Variable	ΔRER		ΔPROD		ΔNFA	
	statistic	p-value	statistic	p-Value	statistic	p-Value
Joint Statistic						
L_c	0.61	1.00	1.30	0.09	0.74	1.00
Individual Parameter Stability Tests						
Error Correction Term	0.10	1.00	0.19	1.00	0.20	1.00
ΔRER	0.14	1.00	0.12	1.00	0.24	1.00
ΔPROD	0.13	1.00	0.90	0.00	0.08	1.00
ΔNFA	0.13	1.00	0.63	0.02	0.30	1.00
Variance	0.12	1.00	0.17	1.00	0.08	1.00

The results in Table 5 indicate that the VECM is structurally stable and therefore we can now move to the estimated BEERs. Taking the cointegration vector, we compute the BEERs over the time period from 1994:1 to 2002:4 and compare them with the actual real exchange rates. Figure 6 shows both series, along with deviations of the real exchange rate from the BEER. During the period of sharp appreciation real exchange rate and BEER have been mostly in line. After mid-1997, however, the BEER remained fairly stable, while the real exchange rate fluctuated with periods of over- and undervaluation between 0 percent and 8 percent. At the end of 2002, the real exchange rate was undervalued by slightly more than 3 percent relative to the BEER. The predominant impression to be gleaned from Figure 6 is that renminbi undervaluation is frequently exaggerated.[26]

Figure 6: Real Effective Exchange Rate, BEER (Upper Panel), and Misalignment (Lower Panel)



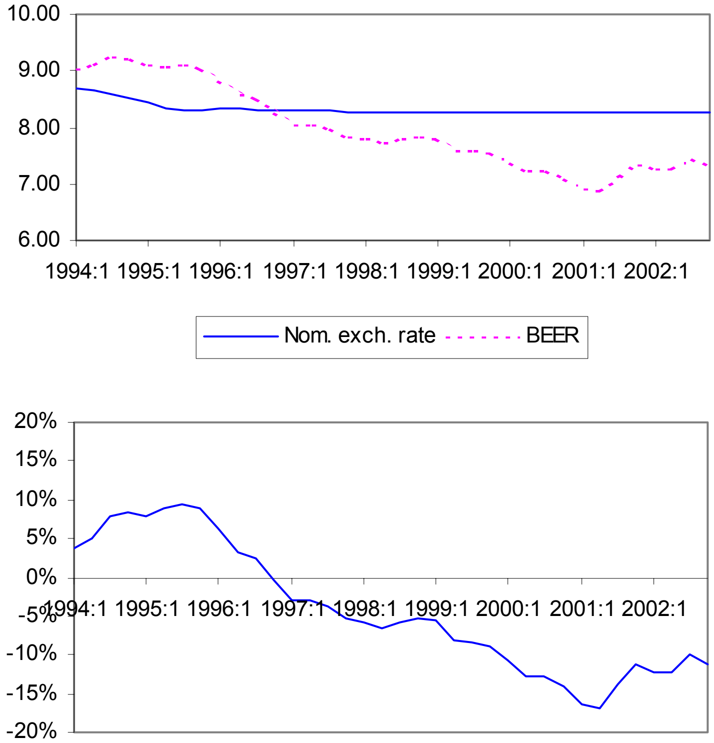
So far, we have calculated multilateral real equilibrium exchange rates. These rates, however, tell us nothing about any over- or undervaluation of the Chinese renminbi against the US dollar. For the current discussion, it is thus far more informative to evaluate nominal bilateral exchange rates. Fortunately, once we have determined the multilateral rates, calculating bilateral nominal exchange rates is only a minor step. The underlying idea is that in a entire world set-up (here, a country "rest of

[26] Since BEERs are a function of sample data, the point estimates that emerge from the procedure should be treated with caution. In other words, the equilibrium exchange rates are a statistical estimate rather than fixed numbers. This point is elucidated in Detken et al. (2002), who employ a wide range of modeling strategies and show that the deviation from the estimated equilibrium is surrounded by some non-negligible uncertainty. This suggests a cautious interpretation of the magnitude of undervaluation.

the world" that enters the analysis neutrally has to be defined) cross-rates between countries can be used to exactly identify each bilateral exchange rate. The detailed procedure has been formalized by Alberola et al. (1999) and appears in the appendix.

The results from this algebraic transformation appear in Figure 7. The nominal renminbi exchange rate against the US dollar and the computed bilateral BEER are presented in the upper panel; deviations from equilibrium are shown in the lower panel. The picture is clearly different from the real exchange rate case. After an overvaluation up to mid-1996, the renminbi has been constantly undervalued against the US dollar. The peak undervaluation exceeded 15 percent. At the end of the observed period, the renminbi was undervalued by 11 percent in relation to the US dollar.[27]

Figure 7: Nominal US $ Exchange Rate, BEER (Upper Panel), and Misalignment (Lower Panel)

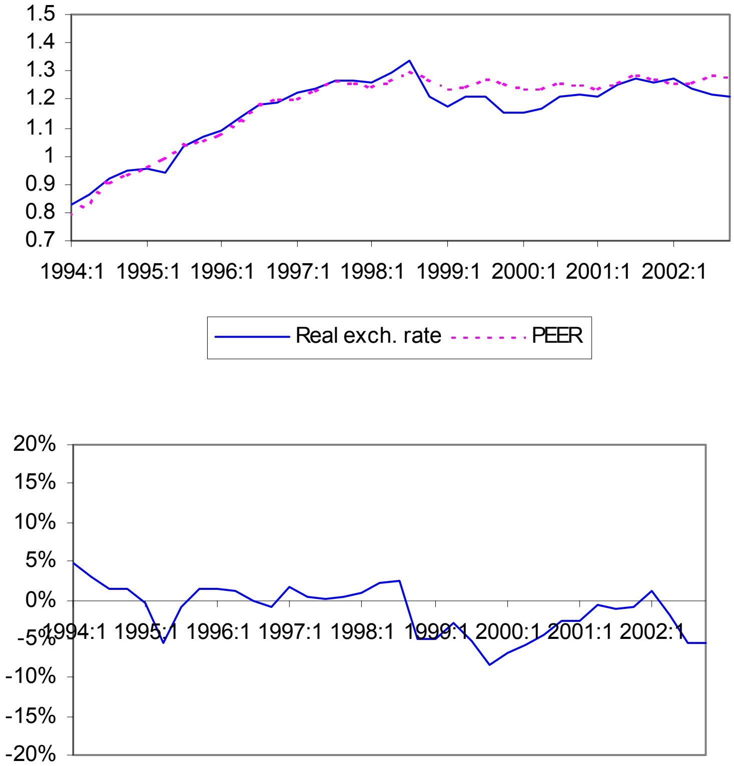


Moving from the BEER to the PEER, we use the α and β vectors from the cointegration analysis to determine the multilateral and bilateral *PEER*. Examining the multilateral real exchange rate case first, Figure 8 shows the somewhat reassuring result that the equilibrium exchange rate estimated using the

[27] The estimates suggest that many of the fears about China's exchange rate policies are unjustified and ignore elementary economics. Despite rapid growth, China's share of world trade is only around 4 percent – about the same as Italy's. Its trade surplus is similar to Canada's, Germany's and Russia's – and it has been shrinking since 1997! Although China has a huge bilateral surplus with the US, it runs bilateral deficits with most of its neighbors, including South Korea, Malaysia, and Thailand.

PEER methodology is generally similar to that estimated using the BEER approach. There are, however, quantitative differences. Undervaluation of the real effective exchange rate was greater than 15 percent at the end of 1999 and almost 6 percent at the end of the sample period.

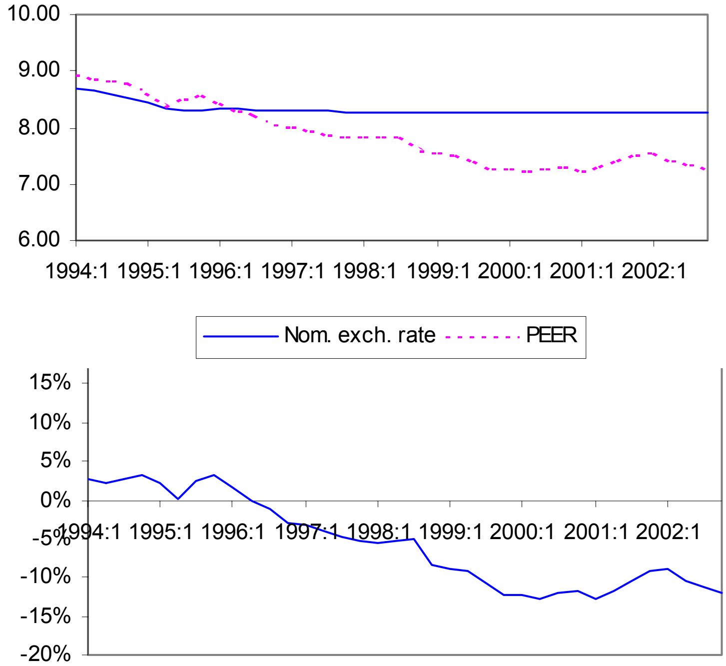
Figure 8: Real Effective Exchange Rate, PEER (Upper Panel), and Misalignment (Lower Panel)



Finally, the nominal bilateral PEER estimates against the US dollar in Figure 9 reinforce the view that the renminbi is not substantially undervalued. The estimated degree of undervaluation at the end of the sample period turns out to be 12 percent, again suggesting that claims of misalignment of the renminbi have been exaggerated. [28]

[28] This conclusion is also consistent with the evidence from trading in non-deliverable forwards (NDF´s) on China´s renminbi [see Ma et al. (2004), p. 86]. China's accession to the WTO has required a great deal more trade liberalization on China's part than its trading partners. One possibility is that at the end of the transition period in 2007 China may require additional currency depreciation. On the other hand, the forthcoming abolition of the Multi-Fibre Arrangement will give scope for a substantial expansion of China's exports of textiles and apparel. There are already numerous studies on the impact of China's accession to the WTO and trade liberalisation in general. Almost all of these studies conclude that developed and developing countries will benefit. See OECD (2001, available at http://www.oecd.org/dataoecd/1/49/2085271.pdf) and Yang (2003) for surveys.

Figure 9: Nominal US $ Exchange Rate, PEER (Upper Panel), and Misalignment (Lower Panel)



5. CONCLUSIONS

The results of our analysis have been summarized in previous sections of this paper, so we will be brief. Overall, our principal conclusion is clear. We have demonstrated that a well-founded measure of the equilibrium value of the renminbi may be recovered from a small set of fundamental variables and that this can be used to produce an assessment of the renminbi in terms of periods of misalignment. Basically, we find compelling evidence that the renminbi is not substantially undervalued. In other words, in some circles it appears to have been politically expedient to scapegoat the Chinese currency for economic difficulties elsewhere. Nevertheless, it would be wrong to conclude that China should not revalue its currency. Nor does revaluation necessarily mean an immediate floating of the renminbi. The preferred option would be to choose a gradual two-step reform process for the transition from "fix" to "flex". The first step might be a medium-size (8–12 percent) appreciation of the renminbi, a widening of the currency band to 3–5 percent (from 0.3 percent now), and a switch from the unitary peg with the US dollar to a broader three-currency basket peg, with weightings of roughly a third each for the US dollar, the yen and the euro.[29] By moving to a three-currency basket peg, China would also increase the stability of its overall trade-weighted exchange rate. Once China has strengthened its

[29] It may be more logical for Beijing to scrap Hong Kong's currency peg first. Hong Kong's currency is overvalued. Although many argue that the Hong Kong peg is the source of renminbi stability, it is also a huge headache. In any case, when the renminbi peg ends or Beijing adopts some sort of managed currency band, Hong Kong would have to move. Since Hong Kong already has a first-world banking system, why not unlock its currency first?

financial system enough to permit a liberalisation of capital outflows and the bad debt problems of state-owned banks are resolved, this would set the stage for the adoption of a managed float.[30] For the OECD countries, the immediate effect of an appreciated renminbi would be to curb the pressure of Chinese competition on western jobs. This effect would be short-lived, of course. The Chinese labour market is exceptionally flexible. Wages in China are priced by international demand for Chinese products. When China's competitiveness is under pressure, firms can respond by shifting labor-intensive production inland, where employment costs are cheaper (a structural change the Chinese authorities officially promote).[31] Ultimately, the exchange rate will not determine the competitiveness of an economy with such labour market flexibility and high factor mobility.

[30] In December 2003 China's government began the bailout of the state-owned banks by giving Bank of China and China Construction Bank some $45 billion from its foreign-exchange reserves to shore up balance sheets strained by non-performing loans. The government will not write-off the non-performing loans, but rather allowed the two banks to use the dollars to boost their capital-adequacy ratios and support new (supposedly profitable) lending. In other words, the government did not bail them out directly; it helped them buy them time to grow out of their bad-debt problems.

[31] China, however, still has a very rigid residency registration system such that people more or less have to live in places where they are supposed to stay. When an individual lives in a place without the proper registration document, he/she is not entitled to the social benefits. thus labour mobility is quite limited. Though there are labour from outside, but they typically are to endure much more difficult conditions because of the registration system.

APPENDIX: DERIVATION OF BILATERAL NOMINAL EXCHANGE RATES

The underlying idea of deriving bilateral exchange rates is to make use of cross rates between countries. Consider the exchange rate e_{ij} of country i against country j and rewrite it in terms of an arbitrary numeraire currency (n), such that

$$e_{ij} = e_{jn} - e_{in} . \tag{A1}$$

Substituting this equation in the definition of the real effective exchange rate,

$$q_i = \sum_j w_{ij} \, e_{ij} , \tag{A2}$$

and doing so for all countries $i = 1, \ldots, n$ yields

$$q = (W - I)e , \tag{A3}$$

where $q = (q_1, q_2, \ldots, q_n)'$ and $e = (e_1, e_2, \ldots, e_n)'$. W is the ($n \times n$) trade matrix. I is the identity matrix of order n. One exchange rate in (A3) is redundant and thus can be discarded without losing information. We next define $\overline{q} = (q_1, q_2, \ldots, q_{n-1})'$ as the [(n-1)×1] vector, where the numeraire real multilateral exchange rate has been discarded and $\overline{q}_{num} = (q_n, q_n, \ldots, q_n)'$ as the [(n-1)×1] vector, which consists of the real multilateral exchange rate of the numeraire. Expressing the multilateral exchange rates relative to the numeraire currency gives

$$\overline{q} - \overline{q}_{num} = (\overline{W} - \overline{I})\, \overline{e} - \overline{q}_{num} , \tag{A4}$$

where a line on top of matrices means that the n^{th} row and column have been deleted, and where $\overline{e} = (e_1, e_2, \ldots, e_{n-1})'$ is the [(n-1)×1] vector. Using (A2), it is straightforward to obtain

$$\overline{q} - \overline{q}_{num} = [(\overline{W} - \overline{I}) - \overline{W}_{num}]\, \overline{e} , \tag{A5}$$

where $\overline{W}_{num}$ consists of the vectors $q = (q_{n1}, q_{n2}, \ldots, q_{nn-1})'$ as the rows of the matrix. Pre-multiplying both sides by the inverse of the [(n-1)×(n-1)] matrix $Z \equiv [(\overline{W} - \overline{I}) - \overline{W}_{num}]$ yields the derivation of bilateral equilibrium exchange rates

$$\overline{e} = Z^{-1} \, (\overline{q} - \overline{q}_{num}) . \tag{A6}$$

This method only works if the exchange rate vector encompasses the entire world. Thus, the rest of the world (ROW) must be included in the analysis.[32] Since there is no information about the rest of the world available, the most plausible assumption is that the multilateral real exchange rate of the ROW is permanently in equilibrium. Applying this assumption, we rewrite equation (A6) in terms of deviations from equilibrium

$$\hat{\overline{e}} = \hat{Z}^{-1} \, (\hat{\overline{q}} - \hat{\overline{q}}_{num}) . \tag{A7}$$

The deviations from the estimated real BEERs, respectively PEERs, are known so that bilateral deviations and corresponding nominal BEERs, respectively PEERs, can be calculated.

[32] In practical terms, the trade matrix has to be adjusted including the trade share of the rest of the world.

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