BY HOW MUCH IS THE CHINESE RENMINBI UNDERVALUED?

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Abstract

Recently, there has been a lot of discussion about the value of China´s currency. This paper therefore explores the equilibrium levels of China´s real and nominal exchange rates. Employing the Johansen cointegration framework, we focus on the behavioral equilibrium exchange rate (BEER) model and the permanent equilibrium exchange rate (PEER) model. The results suggest that the renminbi is undervalued against the dollar, but not dangerously so.

Keywords: Renminbi, Yuan, China, Exchange Rate, Equilibrium Exchange Rate
JEL-Classification: F31, F32, F41, C32

1. Introduction

Misalignment in the Chinese currency, the renminbi, has been the focus of much recent interest. China´s currency was devalued in 1994 and since then has been kept at a constant nominal level to the U.S. dollar despite China´s fast economic growth, rising productivity, soaring exports, and huge foreign direct investment inflows – all factors that would normally cause a currency to appreciate.[1] Lastly, the huge build-up of reserves suggests that, left to its own devices, the renminbi would appreciate.

According to the American government, an unfairly undervalued renminbi is keeping Chinese vibrant exports artificially cheap and is leading to job losses in America, Japan and other more sluggish economies in the region. Given China´s strength as a trading nation, the fear is that China is experiencing "high speed" growth by selling deliberately undervalued exports and is becoming the "workshop of the world".[2] With a seemingly infinite pool of underemployed workers in the countryside and in inefficient state-owned enterprises as well as pitifully low wages, China does look as though it could out-compete other economies in the manufacturing of almost anything labor intensive. The response of politicians in America and elsewhere to this perceived threat was to lobby for a change of the Chinese exchange rate regime and an end of the Chinese "currency manipulation".[3] The complaints from Europe are more modest than those from America although the dollar peg produces perverse results in terms of international adjustment processes. When the dollar depreciates, the renminbi depreciates along with it. China´s international competitive position thus strengthens and its current account surplus rises further, placing additional pressure on America´s other trading partners to accommodate the needed reduction in the US current account deficit. Finally, other Asian countries fear that China is consuming too large a share of the region´s foreign direct investment.

If one concludes that a currency is misaligned, then the next issue is to decide by how much. There is substantial disagreement when it comes to calculating how undervalued the renminbi is, with estimates differing wildly.[4] According to the "Big Mac index", which is a regularly published light-hearted

[1] China´s currency is generally known as renminbi, but the unit of measurement is the yuan (the terms are parallels of '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", Worldbank, *Transition Newsletter About Reforming Economies*, available at http://www.worldbank.org/transitionnewsletter/octnovdec02/pgs4-6.htm.

[3] Unfortunately, tensions are rising and the debate has become very much politicized 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] Earlier papers to address the Chinese real exchange rate include that by Chou and Shih (1998) and Zhang (2001a). Chou and Shih investigate movements of the purchasing power parity exchange rate, concluding the renminbi was about 10 percent undervalued at the beginning of the 1990s. Zhang (2001a) has estimated a bilateral US dollar/renminbi behavioural 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

guide to whether world currencies are at their "correct" level, the renminbi was 56 percent undervalued in April 2003.[5] A good dose of appreciation would therefore be required.[6] Recently, the *Economist* has tested whether a Starbucks "tall latte index" reaches the same conclusions as the "Big Mac index".[7] Although the "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 index, the renminbi is only 1 percent undervalued and therefore China should not be an international scapegoat.

Obviously, both burgernomics and lattenomics are distorted because they just consider one good. Therefore, another 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 in 2001, the renminbi was at 0.23, which means the renminbi was more than four times undervalued. The obvious implication is that the renminbi is supercompetitive. How reliable is this extreme result? Figure 2 shows a scatter plot of 135 nations around the world for 2001, with the vertical axis showing the PPP conversion factor divided by the exchange rate and the horizontal axis showing PPP converted per capita *GNI*. China, Hong Kong and the US are marked with arrows.

It seems clear that in developing countries where the per capita income level is relatively low, the currency is generally somewhat undervalued. If this is taken into account, the degree of undervaluation shrinks because the PPP conversion factor to nominal exchange rate ratio does not need to rise to a level of one. When we take to average ratio over the period 1985 – 2001 as a baseline (see the dotted line in Figure 1), then the degree of undervaluation drops from more than 400 percent down to 15 percent.

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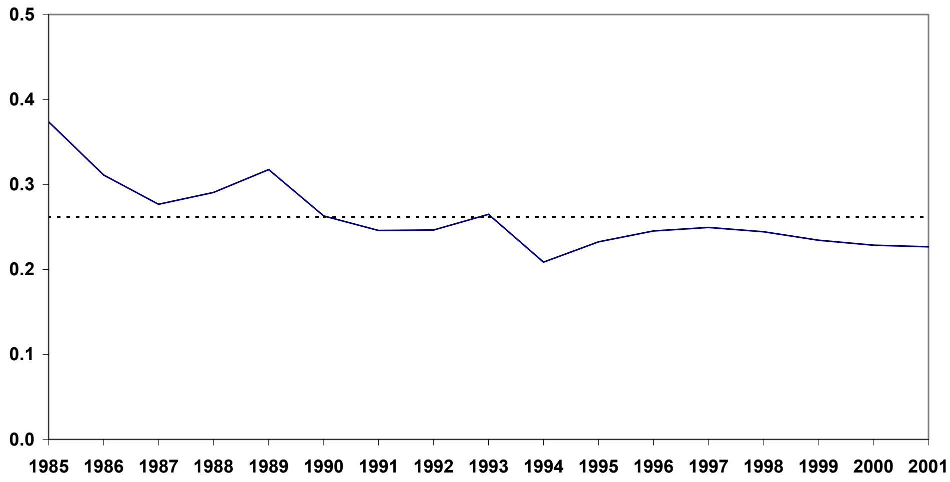
that the actual renminbi exchange rate fluctuated closely around the equilibrium exchange rate, and was close to equilibrium in 1997. On the contrary, Preeg (2003) has recently estimated that unfair Chinese currency manipulation has resulted in a renminbi exchange rate undervaluation of about 40 percent.

[5] The Big Mac "basket" is a McDonald's Big Mac, produced in 110 countries. The Big Mac PPP is the exchange rate that would leave hamburgers costing the same in America 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 its findings, see http://www.economist.com/markets/Bigmac/Index.cfm). Academic economists are taking burgernomics more seriously in recent years, chewing over the Big Mac index in almost a dozen studies [see, for example, Cumby (1996), Ong (1997), Ong (2003), Pakko (1996) and Parsley and Wei (2003)]. Generally, the studies show that the big Mac has been surprisingly accurate in tracking exchange rates in the long run.

[6] Such an undervaluation, however, is not abnormal, but 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.

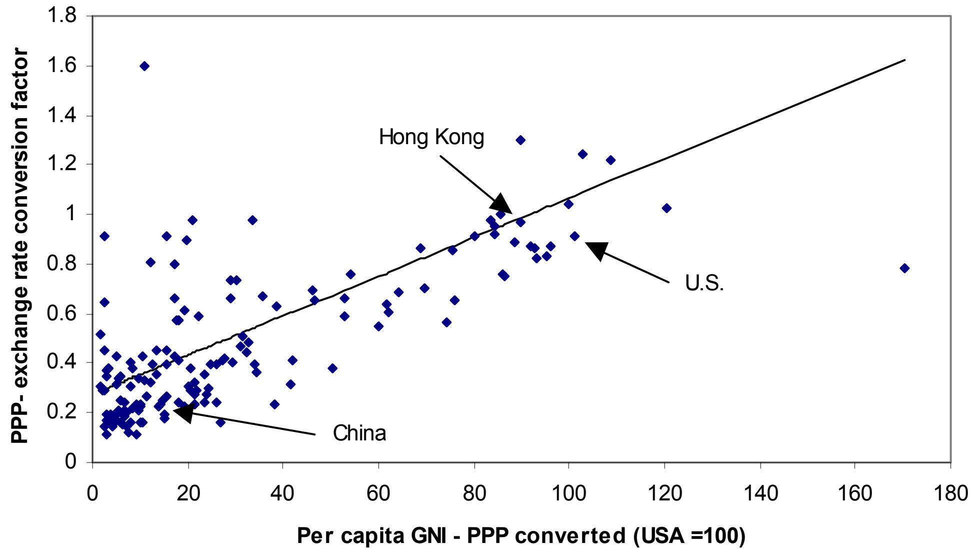
[7] See *Economist*, 17 January 2004, p. 63.

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).

Another recent judgment about the misalignment of the renminbi has been given by Morris Goldstein and Nicholas Lardy in an article published in the *Financial Times* (26 August 2003) and the *Asian Wall Street Journal* (12 September 2003). Their judgment was that the renminbi was undervalued in the range of 15 – 25 percent against the dollar.[8]

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

Against this background, it is the purpose of this paper to derive the equilibrium exchange rate of the renminbi to gauge the degree of misalignment. The necessary steps in calculating the equilibrium exchange rates are sketched in section 2. In section 3 we describe the data used in the empirical analysis in detail. The estimation results are presented in section 4. Finally, in section 5, we summarize the results and conclude. An appendix describes in detail how estimates for bilateral nominal equilibrium exchange rates are derived.

2. Alternative Approaches to Calculating Equilibrium Exchange Rates

In this paper, rather than using PPP exchange rates, we focus on the behavioral equilibrium exchange rate (BEER) model and the permanent equilibrium exchange rate (PEER) model which make the identification of equilibrium exchange rates more rigorous.[9] The equilibrium exchange rates can be thought of as an attractor for the actual exchange rate, pulling the actual exchange rate towards it in.

2.1. Behavioural Equilibrium Exchange Rates

A behavioral equilibrium exchange rate (BEER) effectively involves reduced form modeling of the exchange rate based on standard cointegration techniques. The fundamentals driving the exchange rate are typically the economic factors determining internal and external equilibrium, but 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, however, is rather the data determined systematic component of the exchange rate in the medium and long-run.[10] Consider the real exchange equation

(1) $$q_t = \delta_0 + \delta_1 z_t + \varepsilon_t$$

[9] Both approaches differ not so much in the theory they embody, but instead in the techniques they use to implement the underlying theory.

[10] There is a range of alternative approaches available to estimate equilibrium exchange rates such as BEER, DEER, FEER, PEER or NATREX. Our focus on the BEER and PEER approach reflects the fact that both measures do not require any "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). The Fundamental Equilibrium Exchange Rate (FEER) approach has been proposed by Williamson (1994), and the Natural Real Exchange Rate (NATREX) model has been developed by Stein (1994). The IMF has defined the DEER as essentially the FEER but based on an optimal fiscal policy trajectory. These concepts have been applied on various exchange rate issues, see e.g. 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 on 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

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

The (eclectic) 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. Thus, we get the variable space

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

which will motivate the empirical work. The impact of productivity differentials on the real exchange rate is commonly known as the Harrod-Balassa-Samuelson effect. It states that one country's relatively higher productivity increases are associated with a real appreciation of its currency.[11]

The net foreign asset position affects the real exchange rate through several channels. A worsening of the net foreign position, for instance, means higher interest payments for net debtor countries on their debt and smaller incomes from interest payments for creditor countries. This has to 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.[12] The exact definitions of the variables entering (3) are described in detail in the next section.

The econometric methodology for the application of the BEER approach in this paper is the multivariate cointegration technique as suggested by Johansen (1995). The starting point is a vector-error correction model (VECM)

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[11] China is exactly the type of economy for which the relevance of the Harrod-Balassa-Samuelson effect has been posited: the Chinese economy is characterized by rapid growth, 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.

[12] 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) have motivated the NFA variable from a stock-flow model of the exchange rate.

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

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×(*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×*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.

2.2. Permanent Equilibrium Exchange Rates

One of the problems of the BEER approach is that the variables entering the calculations are not themselves at what is deemed to be equilibrium values. A simple way to measure equilibrium exchange rates therefore is to remove the business cycle from the data using a Hodrick-Prescott or bandpass filter. An alternative procedure is to decompose times series into permanent and transitory components. The transitory component is characterised 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 so-called 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 which provides a direct link to the BEER approach.[13]

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

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

[13] The PEER concept has typically been applied to western industrialized 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 industrialized 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

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

and

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

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)

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

where

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

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

3. Data and (the not-so-trivial) Measurement Issues

It is helpful to begin with a brief sketch of the data. Quarterly data are used for all time series. For the calculation of real effective rates, data from China's three largest trading partners, Japan, the U.S., and Euroland is utilized. 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.

3.1. Real Effective Exchange Rates

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 its main trading partners, Japan, the U.S., and Euroland. Trade with these economies amounted to 47 percent of mainland China´s total trade in 1996. These trade weights are based on cumulated export and import volumes, where exports have been double weighted in order 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.

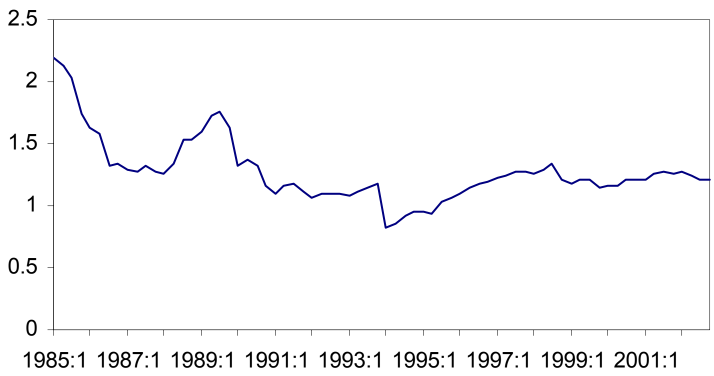
The log real effective exchange rate for country i (q_i) is thus the trade-weighted average of the log bilateral real exchange (e_{ij}) rates vis-á-vis its trading partners:

$$(10) \qquad q_i = \sum_j w_{ij} \, e_{ij}$$

where the trade weights w_{ij} sum up to one $\sum_j w_{ij} = 1$. All exchange rates are average values for the period. Figures for the euro do not exist prior to its introduction in 1999. However, the ECB has published a 'synthetic' value for the nominal euro/dollar exchange rate preceding its introduction, which 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 effective.[14] An "official" rate (a peg to the U.S. dollar which was adjusted several times), an "unofficial" floating rate ("swap" market rate which the central bank occasionally adjusted through market intervention) and an "effective" exchange rate actually faced by exporters (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 onwards, the Chinese authorities repeatedly devalued the official rate, eventually unifying the "official" and "unofficial" exchange rates at the prevailing rate in 1994.[15] 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 thepreciation against the US dollar of the yen. Thereafter, this latter appreciation was reversed as the yen rebounded and as 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: Real Effective Exchange Rate of China, 1985:1 – 2002:4



To cross-check the results, we have compared the calculated real effective exchange rate against the real effective exchange rate for China available in the *World Development Indicators 2003*. These figures match very well, the correlation coefficient turns out to be 0.902 over the sample period 1985 - 2001.[16] This outcome serves to improve our confidence that the real effective exchange rate measure used is not implausible.

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

[15] The deleterious effects of multiple exchange rates (corruption, resource misallocation, rent seeking) are well-known in the literature. China´s various exchange rate regime choices during transition are analysed in Zhang (2001b).

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

3.2. 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 something of a compromise, reflecting the fact that the "right measure" is essentially unobservable due to limited data availability.[17]

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. In practice, 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.

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

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 has been used to extend the time series back to 1985. The same data source publishes annual *PPI* values for China, which have been transformed from low frequency (annual data) to high frequency (quarterly data) using an optimal interpolation procedure.[18] For the euro area a 'synthetic' value for the period prior the introduction of the euro, i.e. up to 1998:4, had to be 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.

3.3. Net Foreign Asset Position

Direct figures on net foreign assets are not available for all countries and all time periods. Instead, we follow an alternative method as suggested by Lane and Milesi-Ferretti (2001). Here, one takes an

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

[18] 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. One has to keep in mind that interpolated data is no substitute for actual data since the greater detail 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 in order to use them together with just a few low frequency series.

initial value of the stock of net foreign assets and adds up current account balances to determine the time series. Unfortunately, in the case of China not even an initial stock was available, so that current account balances were added up historically, starting in 1982. Moreover, Chinese current account data was only available on an annual basis, so that quarterly data had to 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 up. The calculated net foreign assets time series are then seasonally adjusted using the additive *X-12* method when tests suggested seasonality and normalised by nominal *GDP* (in US Dollars) to adjust for the size of each country.[19]

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 the conventional ADF-tests we use the unit root test suggested by Perron (1997). This test has the advantage to allow for a structural break in the time series. Moreover, the timing of the break point is determined endogenously, so that our visual observation can be cross-checked.[20] Table 2 shows the results form the unit root test 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: Perron (1997) Unit Root Tests With Endogenous Breakpoints

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

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

One of the reasons 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

[19] *IFS* data on nominal *GDP* for China are only 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.
[20] One well-known criticism of long-span exchange rate studies relates to the fact that, because of the rather long data spans involved, various exchange rate regimes are typically spanned which may generate structural breaks. This is, of course, a "necessary evil" with large sample sizes and therefore researchers are generally at pains to test for structural breaks.

model is a threshold process [see, for example, Pippenger and Goering (1993, 2000)]. We have therefore additionally employed 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

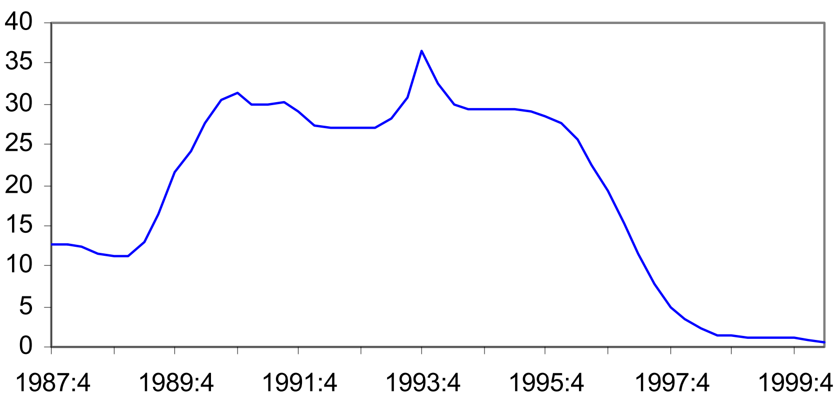
$$(12) \qquad y_t = \alpha + \beta'_1 x_t I\,(q_t \leq \gamma) + \beta'_2 x_t I\,(q_t > \gamma) + e_t$$

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

$$(13) \qquad y_t = \begin{cases} \alpha + \beta'_1 x_t + e_t & \text{if} \quad q_t \leq \gamma \\ \alpha + \beta'_2 x_t + e_t & \text{if} \quad q_t > \gamma \end{cases}$$

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) has suggested a practical and straightforward method to estimate γ using least squares techniques and to construct asymptotically valid confidence intervals for γ.[21] F-tests can then be used to test for threshold effects ($\beta_1 \neq \beta_2$). In other words, the procedure allows to test whether the identified threshold effect is statistically significant. Figure 4 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 4 : *F*-Test Sequence for the Threshold Model



Notes: 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 given the fact that the threshold parameter, γ, is only identified under the alternative hypothesis

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

of nonlinearity. The lack of identification of γ under the null hypothesis distorts the distribution of the test statistic. Hansen (2000) overcomes the problem by using a bootstrapping procedure: using the estimated linear relationship, artificial data on the dependent variable is simulated and both a linear and a piecewise linear model are estimated. The corresponding test statistic is computed and the procedure is repeated a large number of times, leading to an approximate distribution of the test statistic under the null of linearity. Using this procedure with 1000 replications yields that the p-value of a structural break at 1993:4 is P = 0.000.

The F-sequence displays significant structural instability at 1993:4, and, hence, we proceed to subdivide the sample. Thus, from now on we concentrate on the time period from 1994:1, the first period after the devaluation of the renminbi, until the end of the sample, i.e. 2002:4. It is worth emphasizing that this does not have any implications on the time series properties, so that we can now test for cointegration between the variables.[22]

We use the maximum-likelihood methods of Johansen (1995) to determine both the existence of cointegration and the produce estimates of the BEER and PEER. The test statistics are summarized in table 3. A warning note is useful here. We use small samples in our empirical application, and there is evidence that small samples can cause spurious rejection of the null hypothesis of no cointegration. One recommended solution for this problem is to adjust the values of the statistics to take into account small sample size. We have therefore 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	5% Critical Value	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

Notes: The lag length (p = 1) has been chosen as to minimize the Akaike and Schwarz criteria. The small sample correction suggested by Reimers (1992) uses (T-np) as a scaling factor rather than T.

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 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.

[22] 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); net foreign asset position, -4.87 (4).

Table 4. Normalised 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)

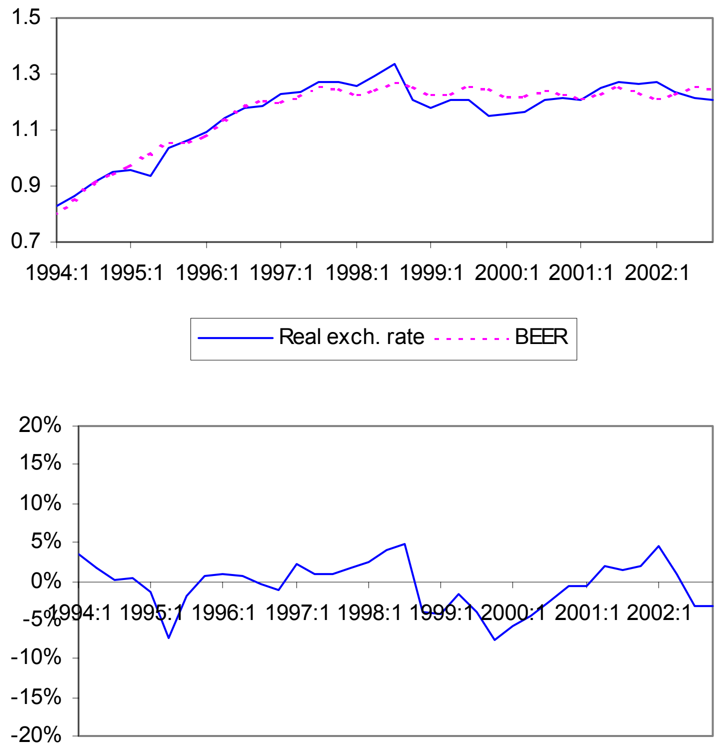
Since we became aware of possible break-points in the regression analysis, we have finally performed Hansen´s (1992) Lagrange multiplier type tests to check for possible parameter instability. The LM-type test statistics test the null hypotheses of parameter and variance constancy in static and dynamic regression equations, that is, 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 will wander around zero. Under the alternative hypothesis of parameter instability the cumulative sums will develop a nonzero mean in parts of the sample and therefore the test statistics will 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 the ECMs be estimated once over the full sample, that is, no sample-split points need to be chosen. They are, however, not designed to determine 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 5 shows both series as well as 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. Since mid 1997, however, the BEER has remained fairly stable on its level 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 5 is that the renminbi undervaluation is frequently exaggerated.[23]

Figure 5: Real Effective Exchange Rate, BEER (Upper Panel), and Misalignment (Lower Panel)



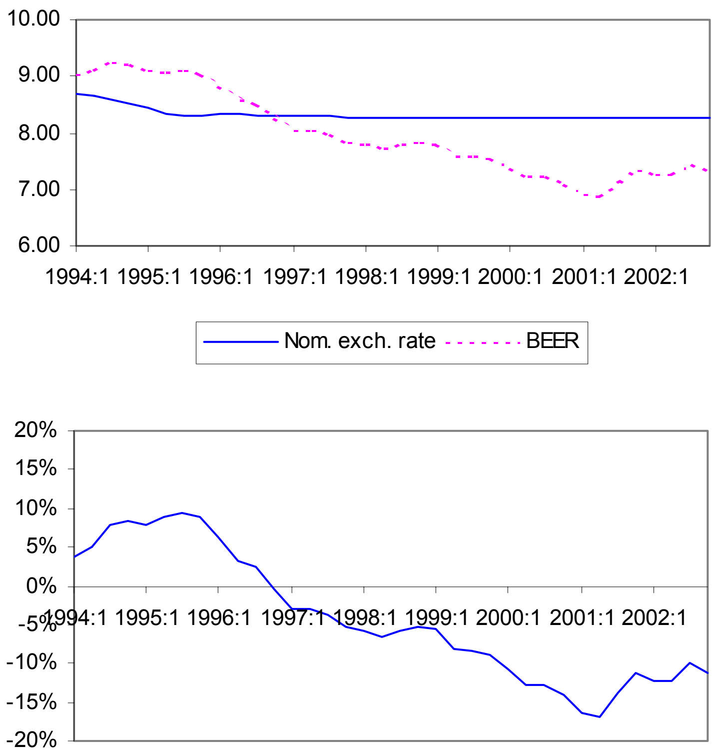
So far, we have calculated multilateral real equilibrium exchange rates. These rates, however, tell us nothing about any over- or undervaluation of the Chinese renminbi against the US $. For the current debate it is thus far more informative to evaluate nominal bilateral exchange rates. Fortunately, calculating bilateral nominal exchange rates is only a small step, once we have determined the multilateral rates. The underlying idea is that in a whole world set-up (for this, a country "rest of the world" has to be defined, which enters the analysis neutrally) 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 can be found in the appendix.

The results from this algebraic transformation appear in figure 6, where the nominal renminbi exchange rate against the US dollar and the computed bilateral BEER are presented in the upper panel and deviations from equilibrium in the lower panel. The picture is clearly different to the real

[23] Since the BEER are a function of sample data, however, 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 a fixed number. This point is also made clear 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.

exchange rate case. After an initial overvaluation until mid 1996, the renminbi has been constantly undervalued against the US dollar, with a peak undervaluation of more than 15 percent. At the end of the observed period the renminbi was undervalued by 11 percent in relation to the US dollar.[24]

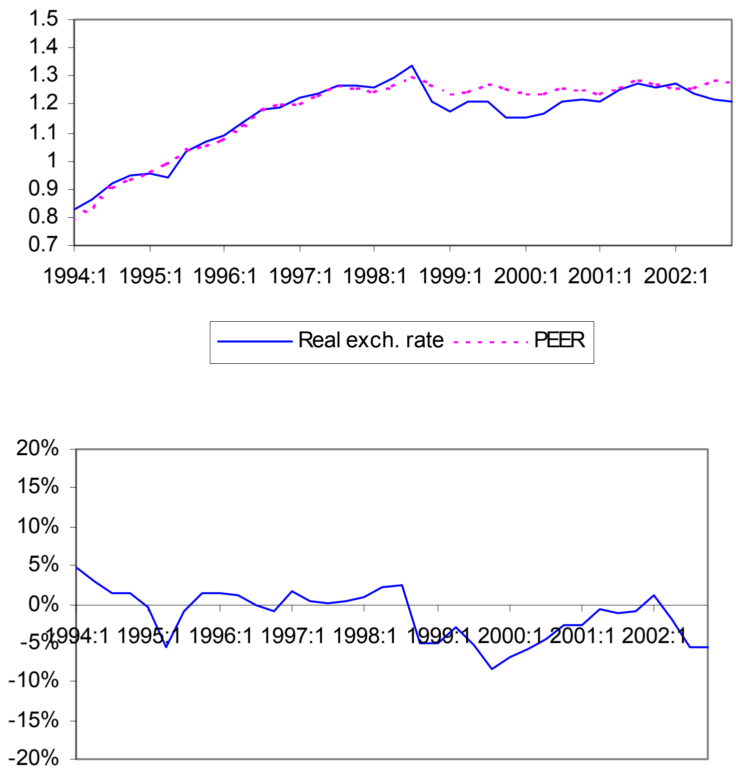
Figure 6: Nominal US $ Exchange Rate, BEER (Upper Panel), and Misalignment (Lower Panel)



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

[24] The estimates reflect that most of the fears that China arouses are wrong and ignore elementary economics. Despite its 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 or even Russia´s; and it has been shrinking since 1997. Although China has a big bilateral surplus with the US, it is running bilateral deficits with most of its supposedly threatened neighbors, including South Korea, Malaysia and Thailand.

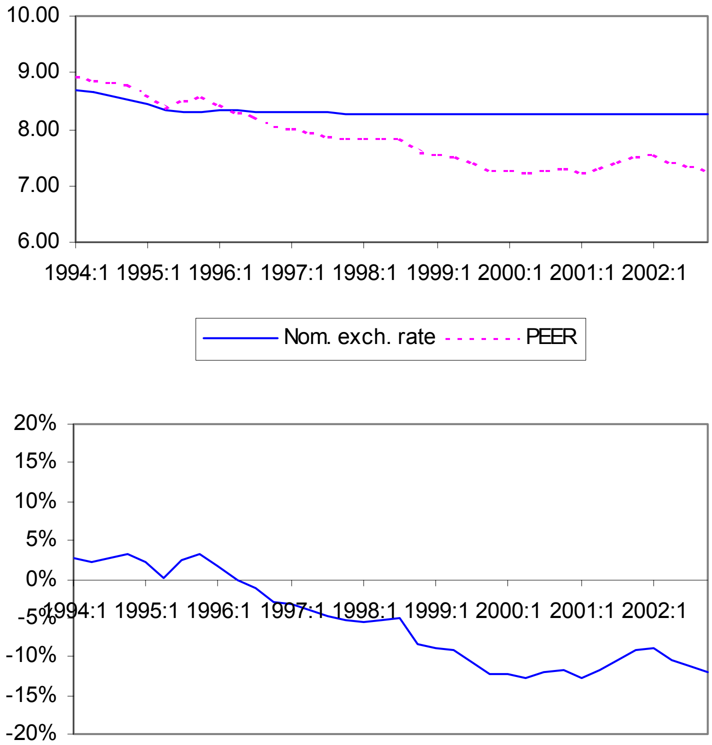
Figure 7: Real Effective Exchange Rate, PEER (Upper Panel), and Misalignment (Lower Panel)



The bottom line? The nominal bilateral PEER estimates against the US dollar in figure 8 again provide compelling evidence 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 and therefore the misalignment of the rennimbi has been exaggerated in the past.[25]

[25] Moreover, China´s accession to the WTO requires very much greater trade liberalization by China than by its trading partners, suggesting that by the end of the transition period in 2007 China than may require some 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 many studies on the impact of China´s accession to the WTO and trade liberalization in general, and 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 8: Nominal US $ Exchange Rate, PEER (Upper Panel), and Misalignment (Lower Panel)



5. Conclusion

The results of our analysis have been summarized in previous sections of this paper, so we will be brief here. 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. Essentially, we find compelling evidence that the renminbi is not substantially undervalued. To some extent, the Chinese currency has therefore been made a scapegoat for economic difficulties in many other countries. But it is wrong to conclude that China should not revalue its currency. A possible revaluation, however, does not mean an immediate floating of the renminbi. A better idea 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 an 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.[26] By moving to a three-currency basket peg, China would also

[26] It may also be more logical for Beijing to scrap Hong Kong´s currency peg first. Hong Kong´s currency is overvalued, while China´s is undervalued. While many argue the Hong Kong peg is the source of its stability, it´s also one of its biggest problems. If the renminbi is set free, or Beijing adopts some kind of managed currency

increase the stability of its overall trade-weighted exchange rate. This may set the stage for the adoption of a managed float as the second step, after China has strengthened its financial system enough to permit a liberalization of capital outflows and after the bank´s bad debt problems are resolved.[27] For the OECD countries, the immediate effect of an appreciated renminbi would be to curb the pressure of Chinese competition on Western jobs. But this will not be significant in the long-run. The Chinese labor market is very flexible. The wages in China are priced by international demand for Chinese products. When China´s competitiveness is under pressure, firms can also respond by shifting labor-intensive production inland where employment costs are much cheaper than on the coast, a structural change the Chinese authorities already want to encourage. Therefore, the exchange rate does not determine competitiveness for an economy with a flexible labor market and factor mobility.

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band, Hong Kong´s peg may be attacked. Since Hong Kong has a first-world banking system, why not unlock its currency first?

[27] In December 2003 China´s government began the bail-out 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 bad loans. The government did not write-off non-performing loans, but the two banks will use the dollars to boost their capital-adequacy ratios and thus to support new, supposedly more profitable, lending. In other words, the government did not bail them out directly, but intends to buy them time to grow out of their bad-debt problem.

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

(A1) $e_{ij} = e_{jn} - e_{in}$.

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

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

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

(A3) $q = (W - I)e$

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

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

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

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

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

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

This method only works if the exchange rate vector encompasses the whole world. Thus, the rest of the world (ROW) must be included in the analysis.[28] 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

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

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

[28] In practical terms, the trade matrix has to be adjusted including the trade share of the ROW.

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