THE WILLIAM DAVIDSON INSTITUTE
AT THE UNIVERSITY OF MICHIGAN

Yuan Real Exchange Rate Undervaluation, 1997-2006. How Much, How Often? Not Much, Not Often

By: Jeff Chen, Wende Deng and David Kemme

William Davidson Institute Working Paper Number 934
August 2008

Yuan Real Exchange Rate Undervaluation, 1997-2006. How Much, How Often? Not Much, Not Often

Jeff Chen
Wells Fargo Financial
800 Walnut Street
Des Moine, IA 50309
jeff.g.chen@wellsfargo.com

Wende Deng
Department of Mathematical Sciences
University of Memphis
Memphis, TN 38152

David M. Kemme
Department of Economics
University of Memphis
Memphis, TN 38152
dmkemme@memphis.edu

8/2/2008

Corresponding author:

David M. Kemme
Department of Economics
University of Memphis
Memphis, TN 38152
dmkemme@memphis.edu
office: 901-678-5408
fax: 901-678-0876

This is a revised version of a paper presented at the 76th annual meeting of the Southern Economics Association, November 18-21, 2006, Charleston, South Carolina. We would like to thank participants at our session for helpful comments and suggestions.

Abstract

Yuan real effective exchange rate misalignment is esitimated in a behavioral equilibrium exchange rate (BEER) model for the period 1997 to third quarter 2007. Using the Beveridge-Nelson decomposition a vector error correction model (VECM) of the exchange rate as a function of macroeconomic fundamentals, including government expenditures, economic openness, the balance of trade surplus, and net foreign assets, is estimated. We find that the Chinese Yuan has been fluctuating moderately around its long run equilibrium value with undervaluation up to 4% and overvaluation up to 6% at various points in time since 1997. This result is consistent with findings of many of the most recent studies employing alternative econometric methodologies to determine the equilibrium exchange rate. While the Yuan real effective exchange rate has deviated from equilibrium, and it is sticky, taking over five years to correct 50% of the short run misalignment, it does not appear to have been consistently undervalued as has been widely argued.

Keywords: Chinese Yuan, Exchange Rate, Misalignment, BEER, Behavioral, Cointegration, ARIMA, VECM, FGLS.

JEL Codes: F31, F41, P33

1. Introduction

With China's massive trade surpluses have come heated debates regarding whether its currency, the Renminbi or Yuan, is undervalued, purposely or otherwise.[1] Intensive research has been conducted to determine the "equilibrium" exchange rate and the magnitude of its potential misalignment. Estimates of Yuan misalignment vary widely – from 14% overvaluation to as much as 50% undervaluation[2]. The wide variation in misalignment estimates may be attributed to the methodology employed, assumptions made, choice of explanatory variables, sample period being studied, the date at which the assessment is made, and subjective judgments of the researchers, *inter alia.*[3] Further, studies of Yuan misalignment using time series data are often subject to severe data limitations. Most required data are reported annually beginning in 1978, the year of China's economic reform. If quarterly data are used, either the period of analysis is shorter or the available variables fewer.

We contribute to this debate by estimating Yuan misalignment with a behavioral equilibrium exchange rate (BEER) model, more suitable for developing or transition economies like China. We employ quarterly data from first quarter 1997 to third quarter 2007, 43 observations. The real effective exchange rate of the Yuan is specified as a function of GDP-normalized fundamental variables: government expenditure, trade openness (as a proxy for commercial policy), trade surplus (as a proxy for the terms of trade), and net foreign assets. We also employ a vector error correction model (VECM) to analyze the short run behavior of the real exchange rate. We find that at different points in time since 1997 the Chinese Yuan has been undervalued up to nearly 4% and overvalued up to nearly 6%. The largest and the most persistent undervaluation occurred in the period from 2003 to 2006, while there was an overvaluation of 4% to 6% at 2002, 2003 and 2007. For the most part this is consistent with previous BEER estimates but there are differences in the magnitude or precise points at which the undervaluation and overvaluation took place. Using more advanced econometric methods, different explanatory variables and slightly longer time series for estimating the equilibrium exchange

[1] See Laurenceson and Qin (2005) and Yang, Yin and He (2005) for a review of the debates.
[2] Zhang (2002) employs a BEER approach and finds that the Yuan has been fluctuating around the equilibrium level. The rate was overvalued by 12% to 14% in 1999. On the other hand, Coudert and Couharde (2005) examine both a Balassa-Samuelson model and a fundamental equilibrium exchange rate (FEER) model to estimate Yuan misalignment. They find that the Yuan is undervalued from 23% to 50% depending on the methodology and the sample. Recently Cheung et al. (2007) with a methodology similar to the B-S approach, an extended PPP approach and controlling for other determinants of the exchange rate, find essentially no statistically significant misalignment.
[3] See Dunaway and Li (2005) for a more detailed explanation of the wide range of estimates.

rate, we do not find persistent undervaluation of the Yuan, but it is "sticky," taking over five years to correct, moving half way back to its equilibrium from any deviation from it, *ceteris paribus*.

In the next section we present a description of the empirical model including a description of the variables and data. A helpful and more detailed review of the concepts, methodologies and previous studies of Yuan misalignment, upon which this section is based, is provided in two appendices. The estimation procedure and results are reported in section 3. Conclusions are offered in section 4.

2. Empirical Model and Data

2.1 The Basic Model

In Appendix 1 we outline the three common methods of estimating exchange rate misalignment. We adopt the BEER approach and the specific methodology in A1.2.3. Following Elbadawi (1994), Montiel (1999b) and Kemme and Roy (2005), we specify the real exchange rate as a function of a vector of macroeconomic fundamental variables, ***F***, as:

$$\text{Log}(e) = f(\mathbf{F}) = f([\underset{+}{\log(\text{GOV})}, \underset{-}{\log(\text{OPEN})}, \underset{+/-}{\text{SURPLUS}}, \underset{-}{\log(\text{NFA})}]) \quad , \qquad (1)$$

where GOV is the ratio of total government expenditures to GDP, OPEN is the ratio of total international trade volume to GDP, SURPLUS is the ratio of trade balance to GDP as a proxy for the terms of trade, NFA is the ratio of net foreign assets to GDP. The expected sign of each coefficient is below the variable.

Log(GOV) is expected to have a positive relationship with the real exchange rate. An increase in the share of government expenditure in GDP typically raises the price level of nontradables more than that of tradables, because the government, relative to private sectors, typically spends more on nontraded goods than on traded goods. Log(OPEN) is expected to impact the real exchange rate negatively because a higher degree of trade openness increases the supply of imported goods and reduces the relative demand for nontradables, leading to a fall in nontradable prices. SURPLUS is a proxy of the (inverse of the) terms of trade because data on the latter is not available. An increase in the trade surplus often indicates a decrease in the export price relative to the import price. This decrease in the relative price level will tend to switch domestic consumers' demand from importables to domestic-made goods. As the price level of tradables is fixed by PPP, the price level of nontradables will rise, and thus leads to an appreciation in the real exchange rate. This is the substitution effect. However, as importables become relatively expensive, domestic consumers' purchasing power will decrease, which leads to less demand for all goods. While tradable prices are fixed by PPP, nontradable prices will fall, and lead to a real exchange rate depreciation. This is the income effect. Therefore, the impact of a change in SURPLUS on the real exchange rate depends on whether the substitution or the income effect is larger. Log(NFA) is expected to negatively affect the real exchange rate. An increase in the net foreign assets of a country basically implies a net capital outflow, which reduces inflation pressure in the domestic market, and thus leads to real exchange rate depreciation, as directly implied by equation (A1.2).

A time trend, TREND, is also included along with the fundamentals to capture other factors that may affect the real exchange rate, for instance, changes in the CPI composition, or changes in consumers' preference. (As suggested by Dufrenot and Egert (2005)).

2.2. Data

Obtaining data may be the most challenging task in the analysis of real exchange rate misalignment in China. Most Chinese data consistent with Western economic definitions are not available prior to 1978. In addition, most data after that year are reported only annually. Relatively few quarterly series are available prior to 1999. As a result we must (1) find proxies that are available quarterly, (2) transform annual data into quarterly by interpolation, or (3) simply leave those variables with no available data out of the model.

Quarterly time series from 1997Q1 to 2007Q3 for the real exchange rate, openness, trade surplus, net foreign assets and the nominal exchange rate are all available from the IMF *International Financial Statistics (IFS)*. However, quarterly real GDP are not available prior to1999 in *IFS*, and quarterly government expenditures are not available before 2000. Because most fundamentals grow in step with GDP it is essential to normalize them with respect to GDP to avoid estimating a spurious relationship.[4] So, we utilized GDP data from the *China Statistical Year Book* for 1997 to1999. Data

[4] For example, since government expenditures tend to be more on nontradables than on tradables, an increase typically implies an increase in the demand for nontradables relative to that for tradables, which in turn implies a rise in the price of

on government expenditures is more difficult to obtain. Quarterly data are unavailable until 2000, and there is no clear proxy available quarterly back to 1997. Nevertheless, government expenditures in China has an obvious seasonal pattern and that pattern has been stable during 2000 to 2007. If we assume that this pattern is the same for 1997 to 2000, it is possible to construct quarterly data back to 1997, by obtaining the OLS estimates of the quarterly shares of the annual government expenditures from 2000Q1 to 2004Q4 and then using these estimates of the quarterly shares of the annual government expenditures to estimate the quarterly values of government expenditures from 1997 to 1999.

All explanatory variables are then deflated by the CPI and normalized by real GDP. Logs are then taken for all variables except the trade surplus, because the latter takes negative values at some times. A detailed description of data is provided in Appendix 2.

3. Estimation Results

3.1. Stationarity tests

Prior to estimating the model we determine whether the variables are stationary or cointegrated. The Augmented Dickey-Fuller (ADF) unit-root test is reported in Table 1. The number of lags in the test specification for each variable is chosen by the minimum Schwarz Information Criteria. All combinations with/without intercept and time trend are considered with the final choices being based on the parameter significance of each of the regressors.

nontradables to tradables. However, in a circumstance where the economy grows rapidly, the magnitude of government expenditures may nevertheless grow even if its *share* in the total national consumption falls. In such a case, the true impact of this variable on the real exchange rate would be negative because of its declining share in aggregate consumption. Therefore, GDP-normalized figures are necessary in order to rule out the spurious implication from an increase in the absolute level.

Table 1. ADF unit root tests

Variable	P-value for I(0)	P-value for I(1)	Conclusion
LOG_REER	0.6778 (lag2)	<.0001(lag1)	I(1)
LOG_GOV	0.6113 (lag5)	<.0001(lag4)	I(1)
LOG_NFA	0.1019(lag4,int,time)	0.0001(lag3)	I(1)
LOG_OPEN	0.4043(lag6)	0.0196(lag5)	I(1)
SURPLUS	0.8886(lag1,int,time)	0.0001(lag1)	I(1)

All variables are I(1) variables. Therefore we can proceed to the cointegration test and cointegrating regression.

3.2. Cointegration tests and the cointegrating regression

For the fundamentals to be appropriate long run determinants of the real exchange rate, it is necessary that the log of real exchange rate moves with those fundamentals in a systematic manner. Given that both the log of the real exchange rate and most of the fundamentals are I(1) variables, it is then necessary that these variables be cointegrated. To test whether such a cointegrating relationship exists, Engel and Granger (1987) suggest a regression of the log of the real exchange rate on the fundamentals using equation (A1.6), which is referred to as static ordinary least squares (SOLS). If and only if the residuals from this regression are stationary, then the regressand is cointegrated with the regressors. The cointegration test is simply a unit-root test on the residuals. Once the cointegrating relationship is verified, equation (A1.6) is then referred to as the *cointegrating regression*. However, if the regressors are endogenous, then the estimates in this static regression will be biased. Furthermore, the asymptotic distributions of the t-ratios depend on "nuisance parameters" (Hayashi, 2000). To correct this, Saikkonen (1991), Phillips and Loretan (1991), Stock and Watson (1993), and Wooldridge (1990) suggest a dynamic ordinary least squares (DOLS) regression. In the DOLS regression, first differences of the regressors and first differences with lags and leads are included along with the original regressors in SOLS. This setup restores the exogeneity condition. To accommodate the remaining autocorrelation in disturbances, the t-statistics need to be re-scaled in testing the significance of parameters (Hamilton, 1994, pp. 608 - 612; Hayashi, 2000, pp. 650 -655).

The results of the SOLS, three DOLS specifications and a ridge regression, to remove multicolinearity, are summarized in Table 2. Specification DOLS1 adds to the regressors the first difference of fundamentals along with leads and lags up to 2 periods except SURPLUS, for which there are lags up to 4 periods. Specification DOLS2 removes insignificant regressors, with p-value > 0.5. Specification DOLS3 removes regressors with p-value > 0.05. The last specification, the ridge regression, reports the results of a ridge regression with all remaining regressors significant (with p-values of 0.08 or less). For this specification all fundamentals in levels have the expected signs; and the Box-Ljung chi-square test for white-noise residuals strongly indicates the adequacy of the model. The adjusted R-square is 0.9335. All variance inflation factors (VIF) also indicate there is no multicollinearity.

To check whether a cointegrating relation exists, the ADF unit root test is applied to the "residuals" from the DOLS3 specification.[5] The test results, also shown in Table 2, strongly indicate that the residuals are stationary with a p-value of <.0001, and a cointegrating relationship between the log of the real exchange rate and the fundamentals exists. Thus, step (2) described in Appendix 1.2.3 yields the cointegrating relation:

$$log\_reer = 4.57076 + 0.00094*time + 0.00438*log\_gov - 0.0679*log\_open + 0.01215*surplus - 0.00487*log\_nfa + \varepsilon \qquad (2)$$

All variables have the expected signs and the positive sign on the coefficient for SURPLUS indicates that the substitution effect of changes in terms of trade is larger than the income effect. Since SURPLUS is a proxy of the reversed terms of trade, the positive sign reflects a negative relationship between the terms of trade and the real exchange rate.

[5] Note that for the cointegration tests the residuals under investigation are *not* those directly generated from *all* regressors in the DOLS regression, but those generated from only the fundamentals *in levels*, with their coefficients estimated from the DOLS, because it is only these variables whose relationship with the real exchange rate is being examined.

Table 2. Cointegrating regression results

	SOLS		DOLS1		DOLS2		DOLS3			Ridge Regression (ridge = 0.15)	
Adjusted R2	0.6797		0.9092		0.9461		0.9335				
P-value of Box-Ljung Test for White noise residual	<.0355		0.001		0.4516		0.5448				
P-value of ADF test on residuals	<.0001(lag5)		0.0001(lag1)		0.0001(lag2)		<.0001(lag2)				
Regressors	**Estimate**	**P-value**	**Estimate**	**P-value**	**Estimate**	**P-value**	**Estimate**	**P-value**	**VIF**	**Estimate**	**VIF**
Intercept	4.52092	<.0001	6.68411	0.0017	7.22502	<.0001	7.17878	<.0001		4.57076	
Trend	-0.00298	0.2662	-0.02612	0.066	-0.02753	<.0001	-0.02403	<.0001	288.1095	-0.00094	0.30625
Gov	0.03308	0.4482	1.01283	0.0526	1.28713	<.0001	1.29621	<.0001	285.702	0.00438	0.71332
Open	-0.25186	<.0001	0.06182	0.84	0.17976	0.0454	0.17318	0.0791	151.0949	-0.0679	0.5179
Surplus	-0.00137	0.9506	0.61947	0.0792	0.8551	<.0001	0.86722	<.0001	146.5092	0.01215	0.79375
NFA	0.20029	0.0043	0.13457	0.5943	-0.06194	0.4752	-0.15707	0.0731	144.9032	-0.00487	0.37901
D_Gov			-0.85877	0.0754	-1.19645	<.0001	-1.18339	<.0001	418.3782	-0.00809	0.73536
D_Open			-0.1676	0.2461	-0.25038	0.003	-0.30643	0.0007	21.68389	0.01754	1.1605
D_Surplus			-0.39681	0.0698	-0.57119	<.0001	-0.59193	<.0001	59.24474	-0.03381	0.91159
D_NFA			0.0014	0.9913							
D_Gov(1)			-0.58148	0.0987	-0.83094	<.0001	-0.82731	<.0001	222.9682	0.00213	0.79863
D_Gov(2)			-0.24343	0.2384	-0.39156	<.0001	-0.3642	<.0001	61.56311	0.00378	1.0039
D_Gov(-1)			0.04531	0.772							
D_Gov(-2)			0.06453	0.3548	0.05556	0.0239	0.04241	0.0879	9.77829	0.01045	1.20985
D_Open(1)			-0.20499	0.3586	-0.19606	0.0084	-0.24945	0.0019	18.68216	0.00314	1.14133
D_Open(2)			-0.22521	0.2637	-0.23871	0.0055	-0.2093	0.0181	28.52188	-0.05	1.02942
D_Open(-1)			-0.02332	0.9403							
D_Open(-2)			0.03182	0.901							
D_Surplus(1)			-0.34168	0.0678	-0.48536	<.0001	-0.50253	<.0001	44.77491	-0.03479	0.91923
D_Surplus(2)			-0.27183	0.0645	-0.37686	<.0001	-0.38274	<.0001	22.88607	-0.0447	0.9916
D_Surplus(3)			-0.15107	0.1627	-0.21493	<.0001	-0.2277	<.0001	11.32411	-0.01392	0.92008
D_Surplus(4)			-0.06466	0.1689	-0.0893	0.0009	-0.10001	0.0006	4.32267	0.00607	0.93808
D_Surplus(-1)			0.17034	0.2766	0.21951	0.0003	0.21934	0.0006	20.09597	-0.03702	1.03366
D_Surplus(-2)			0.123	0.3075	0.12651	0.0019	0.14052	0.0015	10.8984	-0.04007	1.00505
D_Surplus(-3)			0.08998	0.117	0.10619	0.0014	0.10965	0.0021	7.12415	-0.03079	1.03179
D_Surplus(-4)			0.03989	0.2162	0.04739	0.031	0.04803	0.0473	4.32413	-0.03201	1.03267
D_NFA(1)			0.08931	0.6852							
D_NFA(2)			0.20325	0.2975	0.18642	0.0065	0.12987	0.0337	24.8668	0.04666	0.98978
D_NFA(-1)			0.21279	0.3505	0.14228	0.0659					
D_NFA(-2)			0.09382	0.5727							

Note: D_XXX(n) is the n-period lead of the difference of variable XXX, D_XXX(-n) is the n-period lag of the difference of variable XXX. All variables except SURPLUS are in logarithms.

3.3. The ARIMA Structure and Permanent Values of the Fundamentals

Since we have estimated a systematic long run relationship between the log of the real exchange rate and the fundamentals, we can use this relation to calculate the equilibrium real exchange rate by substituting the permanent (i.e. sustainable) components of the fundamentals into the cointegrating equation. The permanent components of the fundamentals are obtained using the Beveridge-Nelson (B-N) decomposition[6]. However, in order to implement the decomposition it is first necessary to identify the ARIMA structure of each fundamental, because how a variable is decomposed depends on its ARIMA structure. The model identification is done by repeatedly investigating and comparing: (1) the pattern of the sample autocorrelation function (SACF) of the residuals from each model for each variable, (2) the Box-Ljung chi-square test for white-noise residuals, (3) the statistical significance of the parameters, and (4) the AIC and SIC values. The best models found are those that exhibit small and patternless SACF, pass the Box-Ljung white-noise test on residuals, have significant coefficient estimates for critical regressors and have roughly the smallest AIC and SIC values. These are indicated in Table 3.

Table 3. ARIMA model of each fundamental variable

Variable	**Model**	**p-value for Box-Ljung test**
LOG_REER	ARIMA(1,1,1)	0.8603
LOG_GOV	ARIMA(4,1,4)	0.1670
LOG_OPEN	ARIMA(5,1,4)	0.4430
SURPLUS	ARIMA(3,1,0)	0.3910
LOG_NFA	ARIMA(3,1,5)	0.2280

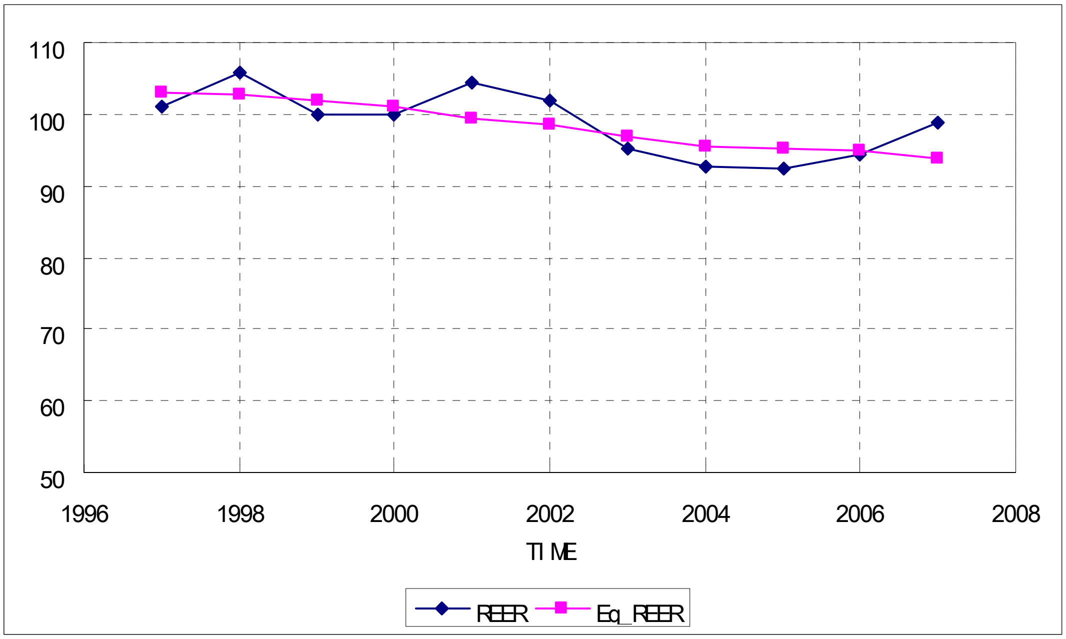
3.4. Equilibrium real exchange rates and misalignments

The ARIMA model of each variable then determines how it is B-N decomposed. The permanent components in the B-N decomposition include the intercept or constant term, the time trend and the stochastic trend, if each exists. The equilibrium values of the log of real exchange rate is then

[6] Beveridge and Nelson (1981).

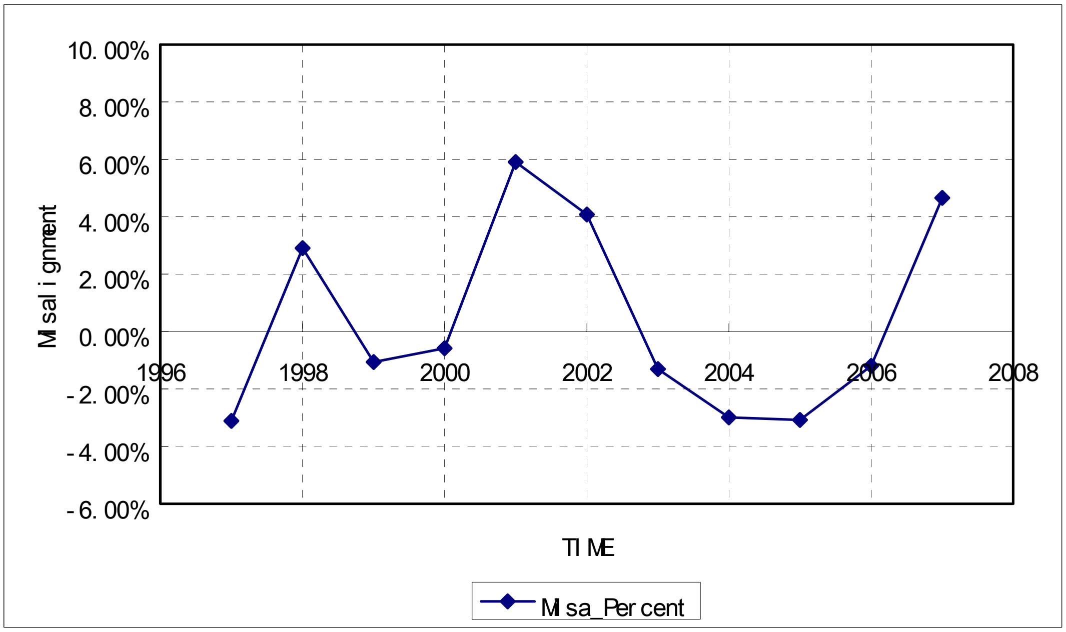
calculated by substituting these components of the fundamentals into equation (A1.7) with the coefficients estimated from the cointegrating regression equation (A1.6). The misalignments are then calculated as the difference between the equilibrium rates and the actual rates. The actual and equilibrium real exchange rates are plotted in Figure 1 and the misalignments in percentages of the equilibrium Yuan are plotted in Figure 2.[7]

Figure 1. Actual and equilibrium real effective exchange rate of Yuan



[7] As the estimation is based on quarterly data, there is no surprise that seasonal fluctuation appears in both the equilibrium real exchange rate and the misalignment, especially when government expenditures as one of the explanatory variables exhibit strong seasonal patterns. Annual averages are hence taken to gain smoother pictures.

Figure 2. Yuan Misalignment in % of the equilibrium value



As indicated in Figures 1 and 2, the Chinese Yuan has been fluctuating around its equilibrium during the sample period, 1997 to 2007, with overvaluation up to 6% in 2001 and undervaluation nearly 4%. The largest and also the most persistent undervaluation occurred from 2003 to 2006. Overvaluation occurred in 1998, 2001, 2002 up to 6% and was about 4% in 2007.

These results are basically consistent with many pervious studies using the BEER approach. For instance, Zhang (2002) found overvaluation in 1998 and 1999 (the end of his sample period); Funke and Rahn (2004) found undervaluation from 1999 to 2000, and in late 2002; they found overvaluation from 1996 to 1998, and from 2000 to 2002; Wang, Hui and Soofi (2007) found overvaluation from 1996 to 2001, and undervaluation in 2003. The magnitudes of misalignment vary among different researchers with most of the recent estimates being much less than 25%. For example, estimates found by Cheung et al. (2007), are not statistically different from zero. Another feature of our findings is that the overvaluation and undervaluation are more evenly distributed around the equilibrium than that often found by other approaches. That is, we find the Chinese Yuan has not been systematically over or undervalued over time. Furthermore, we find that the overvaluation and undervaluation are not very different in magnitudes from one another.

3.4. Short run behavior of the real exchange rate

The existence of the cointegration relationship ensures the existence of a vector error correction mechanism (VECM) as in equation (A1.8). This model specifies the short run movement of the real exchange rate as a function of (1) changes in the fundamentals in the same period, (2) changes in the short run determinants in the same period, and (3) the error correction term in the pervious period. The error correction term is calculated as the difference between the actual real exchange rate and the rate "fitted" by the fundamentals *in levels* with the parameters estimated from the DOLS cointegrating regression (equation (A1.6)).[8] Clearly, the error correction term, which is the difference between the actual exchange rate and the rate predicted by the fundamentals,[9] plays a crucial role in the self-correction of the real exchange rate toward that rate implied by the long run determinants (i.e., the fundamentals). The VECM is specified with the following exogenous short run determinants of the real exchange rate: the log of the nominal exchange rate, LOG_NEER. Results of the estimation of four different specifications of the VECM are summarized in Table 4.

Table 4. Vector Error Correction Model Estimates

	Specification1		**Specification2**		**Specification3**		**Specification4**	
R Square	0.9383		0.9756		0.9979		0.9978	
DW p-value	Pb<DW =0.0007	Pb>DW =0.9993	Pb<DW =0.7161	Pb>DW =0.2839	Pb<DW =0.6498	Pb>DW =0.3502	Pb<DW =0.7156	Pb>DW =0.2844
BIC	-293.97591		-252.61702		-290.17113		-293.39966	
White test p-value	<.0441		<.0111		0.3928		0.3945	
ARCH test p-value	0.8378(order1) 0.6137(order2) 0.7798(order3)		0.4080(order1) 0.6598(order2) 0.6461(order3)					
Ramsey RESET Test p-value	0.2305(power2) 0.4876(power3) 0.5540(power4)		0.6565(power2) 0.5948(power3) 0.2921(power4)					
Regressors	**Estimate**	**p-value**	**Estimate**	**p-value**	**Estimate**	**p-value**	**Estimate**	**p-value**
Intercept	-0.00816	0.0001	-0.018	<.0001	-0.017	<.0001	-0.0172	<.0001
Time	0.000328	0.0001	0.000518	0.0001	0.00043	0.0001	0.000434	<.0001
Err_lag	-0.0148	0.6148	-0.0183	0.6262	-0.0286	0.1615	-0.0297	0.1382

[8] Note that in calculation of the error correction term the explanatory variables used are *only* the fundamentals *in levels* whereas the parameters of these fundamentals are the estimates in the dynamic cointegrating regression in which the fundamentals in first difference with leads and lags are also included as regressors. So, the calculated error correction term is *not* simply the difference between the actual real exchange rate and its *fitted* value.

[9] The misalignment is the difference between the actual real exchange rate and that implied by the *permanent* components of the fundamentals, whereas the error correction term is the difference between the actual rate and that implied by the *permanent and transitory* components of the fundamentals. Thus, the misalignment may be interpreted as the deviation from the long run equilibrium, whereas the error correction is the deviation from the short run equilibrium.

Gov_d	-0.0103	0.1035	0.0286	0.0298	0.0257	0.0012	0.0263	0.0004
Surplus_d	0.00203	0.6956	-0.00799	0.2319	-0.00143	0.6309	-0.00151	0.6031
Open_d	-0.00654	0.5477	-0.0313	0.1649	-0.0373	0.0014	-0.0376	0.0006
Nfa_d	-0.0101	0.3224	-0.0225	0.3441	0.008104	0.4295	0.008057	0.4206
Neer_d	0.9628	<.0001	0.9491	<.0001	0.9947	<.0001	0.9943	<.0001
Gov_d1			0.0462	0.014	0.0279	0.0127	0.0281	0.0084
NFA_d1			0.033	0.0724	0.006658	0.4778	0.007344	0.4137
Gov-d2			0.0564	0.0083	0.0375	0.0196	0.0381	0.0145
Gov_d3			0.0623	0.0058	0.0517	0.0037	0.0526	0.0022
Neer_d3			-0.1175	0.0311	-0.1438	<.0001	-0.1449	<.0001
Gov_d4			0.0337	0.0601	0.0437	0.0034	0.0444	0.0022
Surplus_d4			0.00506	0.3133	-0.00142	0.5603	-0.00145	0.5347
NFA_d4			0.0335	0.0636	0.0345	0.0008	0.0352	0.0003
Gov_d5			0.0443	0.0017	0.0531	<.0001	0.0541	<.0001
NFA_d5			0.013	0.4265	0.0468	<.0001	0.0468	<.0001
Neer_d5			-0.1765	0.005	-0.1415	0.0002	-0.1419	<.0001
AR1					0.0419	0.7453		
AR2					-0.6027	0.0006	-0.5896	<.0001
AR3					-0.1163	0.3552		
AR4					0.8709	<.0001	0.9386	<.0001

In specification 1 of Table 4, only the lagged error correction term, the first differences in fundamentals and the exogenous variables are included. The Durbin-Watson test indicates positive autocorrelation in disturbances. The Lagrange Multiplier (LM) test for ARCH has a p-value of 0.8378 indicating that there is no heteroscedasticity. Moreover, the Ramsey RESET test shows that there is no misspecification with a p-value of 0.2305. To further clarify the source of the correlation or misspecification, up to five lags of the differenced regressors are included to form specification 2. With these additions the LM test for ARCH yields a p-value of 0.0811 indicating no evidence of heteroscedasticity at the 5% significance level. Whie the R^2 improves and there is no positive autocorrelation in this model, the White-noise tests are not adequate, with a p-value <0.0111. To correct this, feasible generalized least squares (FGLS), Yule-Walker method, is used to estimate Specification 3, with the autoregressive order being set to four. The Durbin-Watson test indicates that autocorrelation is not present and the white-noise test indicates the adequacy of the model with a p-value of 0.3928. To remove irrelevant regressors, a Backward Selection method is used to yield Specification 4. In this final specification, the DW, White, Breusch-Pagan and LM tests show no evidence of autocorrelation or heteroscedasticity; and the Ramsey RESET test shows no indication of misspecification. The SIC value is almost the smallest among all specifications as well, and we therefore use the parameter estimates from this specification to calculate the half life to correct a 50% short run over or undervaluation.

The parameter estimate of the error correction term being -0.0297 has two important implications. First, it has the expected negative sign, which indicates that the short run overvaluation (undervaluation) of the real exchange rate in one period implies depreciation (appreciation) pressure in the next period.[10] Second, the magnitude of this parameter reflects the speed at which the real exchange rate corrects itself from the short run over- or undervaluation. The half life of the correction can be calculated by solving

$$0.5 = \left(1 - \left|-0.0297\right|\right)^{T} \qquad \text{for } T,$$

where T is the number of periods (quarters in our case) to correct 50% of the short run over- or undervaluation. We find that T = 22.99 quarters, or 5.75 years. Therefore, the value -0.0297 of this error correction coefficient indicates that it takes about 23 quarters on average for the real exchange rate to correct half way back to its *short run* equilibrium, *ceteris paribus*. Because the government controls the nominal value of the exchange rate, the adjustment must come through the fundamentals and price levels.

4. Conclusion

We estimate Chinese Yuan misalignment for the period 1997Q1 to 2007Q3 using the BEER approach where the real effective exchange rate is a function of GDP-normalized government expenditures, trade openness, trade surplus (as proxy for terms of trade), and net foreign assets. Cointegration analysis assures the long run systematic relationship among these variables. A dynamic ordinary least squares (DOLS) regression and the augmented Dickey-Fuller test on the residuals verify that the cointegrating relation holds. The equilibrium real exchange rate is estimated by substituting the permanent components from a Beveridge-Nelson decomposition of the fundamentals into the estimated cointegrating relation. The misalignment is then calculated as the difference between the actual real exchange rate and the equilibrium rate. A vector error correction model

[10] It is again worth noting that the overvaluation or undervaluation implied by the *error correction term* is different from that implied by the *misalignment*. The former is a short run concept because the benchmark used includes *both* the permanent *and* transitory components of the fundamental variables. The latter is a long run concept because the benchmark used only includes the *permanent* components of the fundamentals.

(VECM) estimated with feasible generalized least squares (FGLS) is then employed to estimate the short run behavior of the real effective exchange rate.

Our results suggest that the Yuan has been undervalued up to 4% and overvalued up to 6% at various points of time within the sample period. Most of the undervaluation occurred from 2003 to 2006. Overvaluation occurred in 1998, 2001, 2002 and 2007. This finding is basically consistent with most previous studies using the same BEER approach with different variables and different sample periods, in that the real effective exchange rate for the Yuan has not deviated from the equilibrium as much as has been widely argued. Our findings also agree with Cheung, Chinn and Fujii (2007) in that the Yuan undervaluation might have been over-estimated in previous studies.[11] Further, the VECM estimation reveals that the Yuan has a self-correction mechanism which takes 23 quarters on average, *ceteris paribus*, to correct half of its short-run under- or overvaluation. It is also worth noting that we examined the trade weighted real effective exchange rate and our results cannot immediately be interpreted as reflecting the properties of the Yuan vis-à-vis a particular currency. It is possible that the Yuan may be overvalued in this aggregate sense but undervalued bilaterally vis-à-vis a particular currency.

[11] Cheung, Chinn and Fujii (2007) adopt the B-S approach, which is different from ours, and find that the Yuan undervaluation, if any, was within one standard error of the regression, and thus was statistically insignificant. Their is more meaningful than the typical B-S approach because they employ panel data rather than a cross section or one time series and control for many other determinants of the exchange rate not typical of previous studies.

References

Abeysinghe, T. and Rajaguru G., 2003. "Quarterly Real GDP Estimates for China and ASEAN4 with a Forecast Evaluation, National University of Singapore, Department of Economics, Working Paper # 0404

Baffes, J., Elbadawi, I. A., O'Connell, S. A., 1999. "Single Equation Estimation of the Equilibrium Real Exchange Rate", In: Hinkle L.E., Montiel P.J. (Eds.). Exchange Rate Misalignment: Concepts and Measurement for Developing Countries. A World Bank Research Publication. Oxford University press, New York, New York, pp. 405-464.

Barlow, D., 2003. "Purchasing Power Parity in Three Transition Economies". *Economics of Planning* 36(3), 201-221.

Benassy-Quere, A., Duran-vigneron, P., Lahreche-Revil, A. and V. Mignon, 2004, "Distributing Key Currency Adjustment: A G-20 Panel Cointegration Approach". Institute for International Economics workshop on Dollar Adjustment: How Far? Against What?, May 25, Washington DC.

Bergsten, F. 2003, "The correction of the Dollar and Foreign Exchange Intervention in the Currency Markets". Testimony before the committee on small business, United States House of Representatives, Washington, D.C., June 25th. Available at www.iie.com/publications/papers/bergsten0603-2.htm.

Beveridge, S. and Nelson, C., 1981 "A New Approach to Decomposition of Economic Time Series into Permanent and Transitory Components with Particular Attention to Measurement of the Business Cycle." *Journal of Monetary Economics* 7, 151-74.

Cheung, Yin-Wong, Chinn, Menzie David and Fujii, Eiji,, 2007, "The Overvaluation of Renminbi Undervaluation" *Journal of International Money and Finance*, 26,5: 762-785

Chinn, M. D. 2000a "The Usual Suspects? Productivity and Demand Shocks and Asia Pacific Real Exchange Rates," *Review of International Economics* 8,1: 20-43.

Chinn, M. D. 2000b "Three Measures of East Asian Currency Overvaluation," *Contemporary Economic Policy* 18,2: 205-214

Chou, W. L., and Shih, Y. C. E., "The Equilibrium Exchange Rate of the Chinese Renminbi." *Journal of Comparative Economics*, 26, 1:165-174, March, 1998.

Chow G. C. and Lin A. 1971, "Best Linear Unbiased Interpolation, Distribution, and Extrapolation of Time Series by Related Series." *Review of Economics and Statistics* 53:372-5.

Clark, P. B., and MacDonald, R., 1998, "Exchange Rates and Economic fundamentals: A Methodological Comparison of BEERs and FEERs." *International Monetary Fund Working Paper* WP/98/67, Washington, D.C.

Coudert, V. and Couharde C., 2005, "Real Equilibrium Exchange Rate in China: Is the Renminbi Undervalued?". *Centre D'Etudes Perspectives et D'Informations Internationales (CEPII)* Working Paper 2005-01.

De Broeck, M. and Slok, T., 2001, "Interpreting Real Exchange Rate movements in Transition Countries." *International Monetary Fund*, working Paper WP/01/56.

Dufrenot, G. and Egert, B., 2005, "Real Exchange Rates in Central and Eastern Europe, What Scope for the Underlying Fundamentals?" *Emerging Markets Finance and Trade*, 41,2: pp. 41-59.

Dunaway, S. L. Leigh and X. Li, 2006, "How Robust are Estimates of Equilibrium Real Exchange Rates: The Case of China," IMF Working Paper No. 06/220

Dunaway, S. and Li. X, 2005, "Estimating China's 'Equilibrium' Real Exchange Rate." *International Monetary Fund*, Working Paper WP/05/202.

Edwards, S., 1994. "Real and Monetary Determinants of Real Exchange Rate behavior: Theory and Evidence from Developing Countries." In: Williamson, J. (Ed.). "Estimating Equilibrium Exchange Rates." Institute for International Economics, Washington, DC., pp. 61-91.

Égert, B., Halpern, L. and MacDonald R., 2005, "Equilibrium Exchange Rates in Transition Economies: Taking Stock of the Issues." The William Davidson Institute, Working Paper # 793.

Elbadawi, Ibrahim A., 1994, "Estimating Long Run Equilibrium Real Exchanges Rates." In: Williamson, J. (Ed.). "Estimating Equilibrium Exchange Rates." Institute for International Economics, Washington, DC., pp. 93-131.

Engle, R. and Granger, C., 1987. "Co-integration and Error-correction: Representation, Estimation, and Testing." *Econometrica* 35, 251-276.

Frankel, J., 2005, "On the Renminbi: The Choice Between Adjustment Under A Fixed Exchange Rate and Adjustment Under a Flexible Rate." NBER Working Paper 11274 (Cambridge, Massachusetts: National Bureau of Economic Research).

Funke, M. and rahn, J., 2005, "Just How Undervalued is the Chinese Renminbi?." *The World Economy,* Vol. 8 no. 4, Balckwell Synergy.

Grafe, C. and Wyplosz, C., 1999, "A Model of the Real Exchange Rate Determination in Transition Economies," in M. Blejer and M. Skreb (Eds.), Balance of Payments, Exchange Rates and Competitiveness in Transition Economies. (Boston: Kluwer Academic press), pp. 150-184.

Garton, P. and Chang, J., 2005, "The Chinese Currency: How Undervalued and How Much Does It Matter?" Australian Treasury, www.treasury.gov.au/documents/1042/PDF/08_RMBundervaluation.pdf

Goh, M. and Kim, Y., 2006, "Is the Chinese Renminbi Undervalued?", *Contemporary Economic Policy,* Vol. 24, Issue 1, pp. 116-126.

Goldstein, M., 2004, "Adjusting China's Exchange Rate Policies." Paper presented at the International Monetary Fund's Seminar on China's Foreign Exchange System, Dalian, China, May 26-27.

Granger, C. W. J. and Newbold, P., 1974, "Spurious regressions in Econometrics." *Journal of Econometrics,* 2, 1974,111-120.

Hamilton, J. D., 1994, "Time Series Analysis." Princeton University Press, Princeton, New Jersey.

Hayashi, F., 2000, "Econometrics." Princeton University Press. Princeton and Oxford.

Hinkle, L. E. and P. J. Montiel 1999 *Exchange Rate Misalignment* (New York: Oxford Univesity Press/World Bank)

Isard, P., Faruqee, H., Kincaid, g. and Fetherston, M., 2001, "Methodology for Current Account and Exchange Rate Assessment." International Monetary Fund Occasional paper no. 209.

Jeong, S-E. and Mazier, J., 2003, "Exchange Rate Regimes and Equilibrium Exchange Rates in East Asia." *Revue economique,* Vol. 54, no. 5, September, pp. 1161-1182.

Kemme, D. M. and Roy, S., 2005, "Real Exchange Rate Misalignment: Prelude to Crisis?" William Davidson Institute Working Paper no. 797.

Kemme, D. M., and Teng, W., 2000, "Determinants of the Real Exchange Rate, Misalignments and Implications for Growth in Poland." *Economic Systems* 24(2), 171-205.

Laurenceson, J. and Qin, F., 2005, "China's Exchange Rate Debate." East Asia Economic Research Group Discussion Paper no. 1, School of Economics, The University of Queensland, Queensland.

Lee, J., Milesi-Ferretti, G. M., Ricci, L. and Jayanthi, S., 2005, "Equilibrium Real Exchange Rates: Estimates for Industrial Countries and Emerging Markets" (unpublished: Washington: International Monetary Fund).

Liargovas, P., 1999, "An Assessment of Real Exchange Rate Movements in the Transition Economies of Central and Eastern Europe." *Post-Communist Economies* 11(3), 299-318.

Montiel, P. J., 1999, "Determinants of the Long Run Real Exchange Rate: An Anllytical Model," In Hinkle L. E. and Montiel P. J. (Eds.). Exchange Rate Misalignment: Concepts and measurement for Developing Countries. A World Bank Research publication. Oxford university Press, New York, pp. 264-290.

Phillips, P. C. B., 1986 “Understanding Spurious Regressions in Econometrics.” *Journal of Econometrics,* 33, 1986, 311-340.

Phillips, P. C. B. and Loretan, M., 1991, “Estimating Long-run Economic Equilibria.” *Review of Economics Studies* 58, 165-93.

Saikkonen, P., 1991, “Asymptotically Efficient Estimation of Cointegration Regressions.” *Econometric Theory* 7, 1-21.

Stock, J. H. and Watson, M. W., 1988, “Testing for Common Trends.” *Journal of the Amercian Statistical Association* 83, 1097-1107.

Wang, T. 2004, “Exchange Rate Dynamics.” Chapter IV in Prasad, E. (Ed.) “China’s Growth and Integration into the World Economy,” International Monetary Fund Occasional Paper 232.

Wang, Y., Hui, X. and Soofi, A., 2007, "Estimating Renminbi Equilibrium Exchange Rate", *Journal of Policy Modeling* 29 (2007) 417-429

Williamson, J., 1985, “The Exchange Rate System.” *Analysis in International Economics* 5. Washington: Institute for International Economics.

Williamson, J., 1994, “Estimates of FEERs.” In: Williamson J. (Ed.). “Estimating Equilibrium Exchanges Rates,” Institute for International Economics, Washington, DC. Pp. 177-243.

Wooldridge, J., 1990, “Regression-based Inference in Linear Time Series Models with Incomplete Dynamics.” MIT working paper no. 550, 1-53, April.

Wren-Lewis, S., 1992, “On the Analytical Foundations of the Fundamental Equilibrium Exchange Rate.” In Colin P. Hargreaves, Edward Elgar (Ed.), “Macroeconomic Modeling of the Long Run”.

Yang, J., Yin, H. and He, H., 2005, “The Chinese Currency: Background and the Current Debate.” Working Paper, Center for the Study of Globalization (CSG), the George Washington University.

Zhang, X., 2002, “Equilibrium and Misalignment: An Assessment of the RMB Exchange Rate from 1978 to 1999”, Working Paper no. 127, Standford University.

Zhang, Z., 2001, “Real Exchange Rate Misalignment in China: An Empirical Investigation.” *Journal of Comparative Economics*, 29:80-93, March 2001.

Appendix 1: Concepts, Methods and Previous Work

A1.1 Definitions of the real exchange rate

There are three ways to define the real exchange rate relevant to our purpose: the *internal* real exchange rate, the *external* real exchange rate, and the real exchange rate of *tradable* goods. The *internal real exchange rate,* e_{int}, is defined as the ratio of the price level of nontradable goods to that of tradable goods:

$$e_{\text{int}} \equiv \frac{P_N}{P_T} \quad , \tag{A1.1}$$

where P_N is the price level of nontradable goods, and P_T is the price level of tradable goods. The *external real exchange rate*, e_{ext}, on the other hand, is defined as the nominal exchange rate, *E*, (the foreign currency price of domestic currency)[12] multiplied by the ratio of the domestic price level to the foreign price level:

$$e_{ext} \equiv E \cdot \frac{P^d}{P^f} \quad , \tag{A1.2}$$

where P^d is the domestic price level, and P^f is the foreign price level. The *real exchange rate of tradable goods,* $e_{tradable}$, is defined as the nominal exchange rate multiplied by the price ratio of tradable goods in the domestic country to that in the foreign country:

$$e_{tradable} \equiv E \cdot \frac{P_T^d}{P_T^f} \tag{A1,3}$$

Each of these three definitions is employed for different purposes, and their relationship may be illustrated. The overall price level of all goods in a country can be written as a weighted average of the price of tradables (with weight θ) and nontradables (with weight $1-\theta$):

$$P = \theta \cdot P_T + (1-\theta) \cdot P_N \tag{A1.4}$$

Both the domestic and foreign price levels, P^d and P^f, can be decomposed and substituted into equation (A1.2) to get:

$$e_{ext} = E \cdot \frac{\theta^d \cdot P_T^d + (1-\theta^d) \cdot P_N^d}{\theta^f \cdot P_T^f + (1-\theta^f) \cdot P_N^f},$$

which can be rewritten as:

[12] We define the exchange rate as the foreign price of the domestic currency; hence a rise in the rate represents an appreciation of the currency, whereas a fall represents a depreciation.

$$e_{ext} = \frac{\theta^d + (1-\theta^d)\cdot \frac{P_N^d}{P_T^d}}{\theta^f + (1-\theta^f)\cdot \frac{P_N^f}{P_T^f}} \cdot \left(E \cdot \frac{P_T^d}{P_T^f} \right) \quad , \qquad \text{(A1.5)}$$

where the subscripts T and N refer to tradable and non-tradable goods and the superscripts d and f refer to domestic and foreign.

Substituting the definition of the real exchange rate of tradable goods and that of the internal real exchange rate into equation (A1.4) yields a comprehensive relationship among the three definitions of the real exchange rate:

$$e_{ext} = \left[\frac{\theta^d + (1-\theta^d)\cdot e_{\text{int}}^d}{\theta^f + (1-\theta^f)\cdot e_{\text{int}}^f} \right] \cdot e_{tradable} \quad , \qquad \text{(A1.6)}$$

where e_{int}^d is the internal real exchange rate of the domestic country, e_{int}^f is the internal real exchange rate of the foreign country, and $e_{tradable}$ is the real exchange rate of tradable goods. The nominal exchange rate, *E*, is embedded in $e_{tradable}$.

Equation (A1.6) indicates that both the domestic internal real exchange rate, e_{int}^d, and the real exchange rate of tradables, $e_{tradable}$, are positively related to the external real exchange rate, e_{ext}. For example, suppose that purchasing power parity (PPP) holds for the tradable sector and thus

$$e_{tradable} = 1 .$$

Then the external real exchange rate will be fully determined by the internal real exchange rates of the two countries and the relative prices of tradables and non-tradables in each county. If we further suppose that the internal real exchange rate of the foreign country is relatively stable, then the external rate will be determined mostly by the domestic internal rate. Analysis of the internal real exchange rate is often useful in the analysis of small, open developing economies for several reasons. First, these economies typically have higher growth in their internal exchange rates than developed countries (an implication of the Balassa-Samuelson effect).[13] Second, the exchange rate for tradable goods is stable, being determined on world markets that small open economies cannot affect. Thus,

[13] Developing economies usually have higher growth in labor productivity in the tradable sector. This increases labor demand and hence the wage rate in both the tradable and nontradable sectors. While the price level in the tradable sector is fixed by PPP, the price level in the nontradable sector will rise in accordance with the rising wage. This in turn leads to a rise in the ratio of the price of nontradables to the price of tradables, which is the internal real exchange rate.

for a small, open developing economy, both e_{int}^{f} and $e_{tradable}$ can be thought to be essentially fixed or stable vis-à-vis e_{int}^{d}, and therefore, the behavior of e_{ext} can be reasonably approximated by the behavior of e_{int}^{d}.

The internal real exchange rate has proven to be a useful device to capture Balassa-Samuelson (i.e., the productivity differential) effects, which are believed to play a central role in determination of the behavior of the real exchange rate for developing countries.[14] For example, this definition is used or referred to by Barlow(2003), Chinn (2000b), De Boreck and Slok (2001), Kemme and Teng (2000), Kemme and Roy (2005), Liagrovas (1999), Gaffe and Wyplosz (1999), *inter alia*. However, a major drawback to the measurement of this internal rate is the lack of data on tradable and nontradable prices. Therefore, in empirical research the external rate is used as a proxy for the internal rate. Nonetheless, the internal rate remains a powerful conceptual aid to understanding exchange rate behavior, especially in developing countries. And in our case, because data on tradables and non-tradables are unavailable we focus on the real external exchange rate, using the real effective exchange rate, the trade weighted real exchange rate, rather than a bilateral rate.

A1.2 Determinants of the Equilibrium Exchange Rate

While there are numerous methods to determine the equilibrium exchange rate,[15] most studies of China's currency adopt one of the following three approaches: (1) the fundamental equilibrium exchange rate (FEER) approach, (2) the Balassa-Samuelson relationship (B-S henceforth) approach[16], or (3) the behavioral equilibrium exchange rate (BEER) approach.

A1.2.1 The fundamental equilibrium exchange rate (FEER) approach

The FEER, developed by Edwards(1994, *inter alia*) and Williamson (1985, 1994), is defined as

---

[14] For example, De Broeck and Slok (2001) show that there is strong evidence of productivity-based exchange rate movements for EU accession countries.

[15] See Égert, Halpern and MacDonald (2005) for a comprehensive review and explanation of most of these methods. Also see Dunaway and Li (2005) for a review of applications to the Yuan. They classify the literature slightly differently, as either the "macro-balance" approach, which includes the BEER and FEER approaches, or the "extended PPP" approach.

[16] This approach is also sometimes labeled the purchasing power parity approach or incomes-productivity approach.

the real exchange rate that ensures simultaneous internal and external balance. *Internal balance* is defined as the situation in which an economy functions at full capacity output with low inflation. *External balance* is the "sustainable" or "normal" balance of payments position over a medium term that ensures external debt sustainability. Estimation of the FEER typically takes the following steps (Égert, Halpern and MacDonald, (2005), and Kemme and Roy, 2005):

1) Determination of the steady-state or potential output growth for the domestic and foreign countries, either by empirical calculation (eg., Hodrick-Prescott filter or Beveridge-Nelson decomposition) or by theoretical implication.
2) Determination of a "target" current account position either by a subjective choice of a stable ratio of external debt to GDP (Williamson 1985, 1994), or by regressing the current account on a set of determinant variables, where the fitted value of the current account is taken to be the target value (Isard et al., 2001).
3) Estimation of the relationship between the trade (current account) balance and a set of explanatory variables, including the domestic and foreign outputs and the real exchange rate.
4) Calculating the change in the real exchange rate that is required to bring the actual current account to its target level, using the relationship estimated in step 3. The magnitude of this change in the real exchange rate is then interpreted as the exchange rate misalignment.

There are three major drawbacks with the FEER approach. First, its high complexity requires a large amount of data, which is not available for an emerging economy like China. Second, it involves a large amount of estimation resulting in accumulated uncertainties. This problem is aggravated with the limited and poor quality data available for economies such as China. Third, it may depend heavily on subjective or "normative" judgments as to what the "sustainable" or "target" values should be, and thus tends to generate large variation in conclusions among different researchers.

A1.2.2 The Balassa-Samuelson (B-S) or extended Purchasing Power Parity approach

In contrast to the FEER, the B-S approach is a simple method of estimating the equilibrium exchange rate. This approach basically focuses on the effect of the internal real exchange rate on the (external) real exchange rate, which reflects the Balassa-Samuelson effect. The Balassa-Samuelson hypothesis implies that there is a positive relationship between per capita income and the real exchange rate of a country. Lower per capita income (i.e., lower labor productivity) implies a lower price level for nontradable goods, whereas the price level in the tradable sector is assumed to be fixed by PPP. Hence a lower nontradable-to-tradable price ratio (i.e., the internal real exchange rate) leads to a lower real exchange rate. To see this, recall equation (A1.5) above:

$$e_{ext} = \frac{\theta^d + (1-\theta^d)\cdot\frac{P_N^d}{P_T^d}}{\theta^f + (1-\theta^f)\cdot\frac{P_N^f}{P_T^f}} \cdot \left(E\cdot\frac{P_T^d}{P_T^f}\right) \qquad \text{(A1.5)}$$

Suppose that the real exchange rate of tradable goods, $E\cdot\frac{P_T^d}{P_T^f}$, is fixed to one by PPP, and suppose that the shares of tradable goods in both countries, θ^d and θ^f, are equal, then a lower internal real exchange rate in the domestic (low-income) country, $\frac{P_N^d}{P_T^d}$, relative to that in the foreign (high-income) country, $\frac{P_N^f}{P_T^f}$, implies that the real exchange rate is less than one. The opposite is true for a high income country. Therefore, the real exchange rate of a low income country will be lower than that of a high income country.

Analysis following the B-S approach typically employs a cross-sectional linear regression of the observed real exchange rates of a group of countries on the per capita incomes of that group, and takes the fitted real exchange rate as the equilibrium rate.[17] A recent study of the Yuan, Cheung, Chinn and Fujii (2007), using a similar approach, which they label relative price-relative output approach, expands the typical sample of countries, considers serial correlation and sampling uncertainties and controls for such factors as demographics, capital controls, openness, institutions and savings propensities. They find little evidence of Yuan misalignment. While this approach is generally useful for the determination of the existence of Balassa-Samuelson effects, and in most cases has the advantage of simplicity, low data requirements and independence of normative judgments, for the analysis of the determination of the exchange rate itself it is limited because it typically considers only one determinant of the exchange rate, and thus the results are arguable. In this

[17] There are numerous studies supporting this relationship, e.g. Garton and Chang (2005) pp. 92-93). Some researchers, for example Chou and Shih (1997), use the CPI/WPI ratio instead of the ratio of per capita incomes in the expression for the internal real exchange rate ratio.

literature Cheung, et al. (2007) is an important exception as they control explicitly for other factors which may influence the exchange rate.

A1.2.3 The behavioral equilibrium exchange rate (BEER) approach

The BEER approach directly estimates the equilibrium exchange rate based on a systematic, econometric relationship between the real exchange rate and an appropriate set of explanatory variables. According to Clark and MacDonald (1999), the actual real exchange rate is said to be in equilibrium in a *behavioral* sense when its movements reflect changes in the economic fundamentals that are found to be related to the actual real exchange rate in a well-defined statistical manner. The systematic relationship between the real exchange rate and its fundamental determinants can be identified from the following regression:[18]

$$log(e_t)=\boldsymbol{\beta}'\boldsymbol{F_t} + \varepsilon_t \quad , \qquad \text{(A1.6)}$$

where e_t is the actual real exchange rate at time t, $\boldsymbol{F_t}$ is observations of a vector of fundamentals at t, ε_t is a zero-mean stationary disturbance at t, and $\boldsymbol{\beta}$ is the coefficient vector to be estimated. Note that only when the regression in (A1.6) satisfies a *cointegrating* relation can we say that the variables in (A1.6) move in a systematic manner and hence the explanatory variables are considered appropriate fundamental determinants of the real exchange rate.[19] Once this cointegrating relationship is identified econometrically in regression equation (A1.6), the *equilibrium* real exchange rate is then given by substituting the "sustainable values" or "permanent components"[20] of the fundamentals into that relation:

$$log(e_t^{eqlb}) = \hat{\boldsymbol{\beta}}' \cdot \mathbf{F_t^p} \quad , \qquad \text{(A1.7)}$$

where e_t^{eqlb} is the equilibrium real exchange rate, $\hat{\boldsymbol{\beta}}$ is the estimate of the coefficients obtained from regression equation (A1.6), and $\mathbf{F_t^p}$ is a vector of the permanent components of the fundamentals. These permanent components are obtained by decomposing the fundamentals into transitory and

---

[18] The subsequent BEER specification basically follows the work of Montiel (1999b), Baffes, Elbadawi, and O'Connell (1999), Kemme and Roy (2005).

[19] The reason for requiring a cointegrating relationship is to avoid the problem of "spurious regression" among I(1) variables. Economic time series often follow an I(1) process. If $log(e_t)$ and F_t are both I(1), they may exhibit high correlation and hence a close, but "spurious," relationship even if they are actually independent of each other. I(1) variables have a "true" systematic relationship only if their movements are cointegrated. See Granger and Newbold (1974), and Phillips (1986) for detailed discussions of the spurious regression.

[20] The permanent components of an I(I) variable include the time trend and stochastic trend in a Beverage-Nelson decomposition of that variable.

permanent components. The exchange rate misalignment is then simply the difference between the equilibrium rate and the actual rate.

Then a vector error correction model (VECM) is specified to explain the short run fluctuation of the exchange rate as:

$$D[\log(\mathrm{e}_{t+1})] = \boldsymbol{\gamma}_0 \cdot [\log(e_t) - \hat{\boldsymbol{\beta}}'\mathbf{F}_t] + \boldsymbol{\gamma}_1{}' \cdot D(\mathbf{F}_{t+1}) + \boldsymbol{\gamma}_2{}' \cdot D(\mathbf{X}_{t+1}) + u_{t+1} \quad , \qquad \text{(A1.8)}$$

where *D( )* is the first-difference operator, $[\log(e_t) - \hat{\boldsymbol{\beta}}'\mathbf{F}_t]$ is the *error correction* term, $\hat{\boldsymbol{\beta}}$ is estimated from (A1.6), $\boldsymbol{X_{t+1}}$ is a vector of exogenous variables that are either I(0) or I(1) and has short run effects on the real exchange rate, and $\boldsymbol{\gamma_0}$, $\boldsymbol{\gamma_1}$, and $\boldsymbol{\gamma_2}$ are parameters to be estimated.[21] The error correction term is a self-correcting mechanism for the real exchange rate path. With an expected negative sign, $\gamma_0 < 0$, a positive (negative) value of the error correction term itself, which represents overvaluation (undervaluation) of the actual real exchange rate relative to the equilibrium, at time t, implies a negative (positive) change in the real exchange rate at $t+1$. That is, an overvaluation (undervaluation) in one period is expected to exert depreciation (appreciation) pressure in the next period.

In brief, estimating misalignment via the BEER approach involves the following steps:

1) *Stationarity test of variables*: Identify whether $log(e_t)$ and at least one element in $\boldsymbol{F_t}$ are each an I(1) or I(0) variable.
2) *Cointegrating regression and test*: If the answer in step 1 is positive, then test whether a cointegrating relationship holds for $log(e_t)$ and $\boldsymbol{F_t}$ in the cointegrating regression equation (A1.6), and at the same time obtain the estimate of the coefficient vector, $\hat{\boldsymbol{\beta}}$. In addition, the residuals in this regression will be used as the error correction term in the VECM regression later.
3) *Calculation of the equilibrium exchange rate*: If the cointegrating relation holds, then the equilibrium real exchange rate, e_t^{eqlb}, is calculated using equation (A1.7), where $\hat{\boldsymbol{\beta}}'$ is obtained from regression equation (A1.6) in step 2, and $\mathbf{F}_t^{\mathbf{P}}$ is obtained using either an H-P

[21] Note that the disturbance term, u_{t+1}, in this VECM regression will be stationary given all the precedent requirements of this estimation procedure: $log(e_{t+1})$ is I(1), $\boldsymbol{F_t}$ is a mixture of I(0) and I(1), $log(e_{t+1})$ and $\boldsymbol{F_t}$ are cointegrated, $\boldsymbol{X_{t+1}}$ is either I(0) or I(1).

filter or B-N decomposition.[22] The misalignment in the real exchange rate is the difference between the actual and equilibrium rates.

4) *Error correction regression*: Given the above results, run a regression of the vector error correction model (VECM) specified in equation (A1.8) to estimate the relationship between the real exchange rate and its short run determinants, including how the under- or over-valuation in one period affects the change in the real exchange rate in the next period.

A wide variety of macroeconomic variables have been employed in the specification of the fundamentals in $\boldsymbol{F_t}$. For example, Kemme and Roy (2005) in a study of Poland and Russia use the terms of trade, government expenditures, trade openness and capital inflows. In study of China Funke and Rahn (2004) use CPI/WPI (as proxy of the relative productivity) and net foreign assets; Goh and Kim (2006) use government expenditures, productivity and trade openness; Wang (2004) uses CPI/PPI , net foreign assets and trade openness; and *inter alia*.

Compared to the FEER and the B-S approaches, the BEER approach possesses a number of advantages: First, it is more general in the sense that it is not based on any specific exchange rate model. Second, it is entirely data determined with no normative judgement about a possible equilibrium period. Third, it makes use of more than one (typically three to four) explanatory variable, and thus its explanatory power is more reliable than that of the B-S, which only uses one factor. Fourth, it involves only single equation estimation, so that the estimation uncertainty may be less. Fifth, it is subject to rigorous econometric analysis. Last but not least, it is well suited to developing countries or transition economies in which large and complex models are usually not feasible due to data limitations.[23]

A1.3: Previous Research

As mentioned earlier there have been numerous studies of Yuan misalignment employing each of the above methods. Several of these are summarized in Table A1.1. From this summary it appears that the assumption of PPP in the B-S context leads to large estimates of undervaluation. Whereas the FEER methodology leads to lower estimates and the BEER methodology even lower estimates.

[22] The permanent components are also possible to be obtained by using subjective evaluation of the long-term values. See Baffes, et al. (1999). However, this method is not recommended due to its subjectivity.

[23] See Egert, Halpern and MacDonald (2005), Funke and Rahn (2004) and Zhang (2001).

Dunaway and Li (2005) reach similar conclusions.

Table A1.1 Previous studies of Yuan misalignment

Paper	**Method**	**Misalignment in % of the eqlb. rate**	**Assessment year**	**Explanatory variables in B-S and BEER approaches**
Benassy_Quere et al (2004)	FEER	44% - 47% undervaluation	2003	
Coudert and Couharde (2005)	FEER	27% - 33% undervaluation	2002	
Coudert and Couharde (2005)	FEER	23% - 30% undervaluation	2003	
Garton and Chang (2005)	FEER	15% - 30% undervaluation	2005	
Goldstein (2004)	FEER	15% - 30% undervaluation	2003	
Jeong and Mazier	FEER	33% undervaluation	2000	
Wang (2004)	FEER	Small	2000 - 2002	
Wren-Lewis	FEER	28% undervaluation	2002	
Cheung, Chinn and Fujii (2007)	B-S	Small	1975-2004	PPP per capita income
Chou and Shih (1997)	B-S	7.6 % undervaluation	1994	WPI/CPI
Coudert and Couharde (2005)	B-S	49% undervaluation	2002	PPP per capita income
Coudert and Couharde (2005)	B-S	41% - 50% undervaluation	2003	PPP per capita income
Frankel (2004)	B-S	36% undervaluation	2000	PPP per capita income
Garton and Chang (2005)	B-S	25% undervaluation	2000	PPP per capita income
Funke and Rahn (2004)	BEER	3% undervaluation	2002	CPI/WPI, Net foreign assets
Goh and Kim (2006)	BEER	Small	2000 - 2002	Government expenditures, Productivity, Openness
Wang (2004)	BEER	5% undervaluation	2003	CPI/PPI, Net foreign assets, Openness, and 4 dummies
Wang, Hui and Soofi (2007)	BEER	3% undervaluation	2004	Terms of Trade, per capital GDP, Money Supply, Foreign Exchange Reserve
Zhang, Xiaopu (2002)	BEER	14% overvaluation	1999	Terms of Trade, Productivity, M2, Net foreign assets
Zhang, Xiaopu (2002)	BEER	12% overvaluation	1997 - 1998	Terms of trade, Openness, Government expenditures
Zhang, Zhichao (2001)	BEER	Small	1997	Investment, Government expenditures, Export growth,

Appendix 2: Description of Data

CPI
Source: IFS database, IMF
Original data format: Annual growth rates of quarterly CPI
Estimation: quarterly CPI in levels are estimated by using the assumed base values in the year 2000 as Q1:100, Q2:100, Q3:99.25, Q4:100, which gives the least seasonal effects.

GDP (Real GDP in billions of Yuan)
Source: IFS database, China Statistic Book
Original data format: quarterly GDP in billions of Yuan
Data range: 1997.Q1 – 2007.Q3

REER (Real Effective Exchange Rate of Yuan):
Source: IFS database, IMF
Original data format: quarterly Real Effective Exchange Rate of Yuan
Transformation: into Logs

GOV (Real government expenditures in shares of real GDP)
Source 1: Ministry of Finance, China: http://www.mof.gov.cn/1162.htm
Original data format: nominal annual values in 100 millions of Yuan
Data range: 1997 – 2007
Source 2: National Economic Research Institute, China:
http://www.neri.org.cn/h_fenxi_ji.htm
www.mof.gov.cn
big5.china.com.cn/economic
Original data format: nominal quarterly values in 100 millions of Yuan
Data range: 2000.Q1 – 2007.Q4
Estimation 1: Quarterly shares of GOV in Annual figures are estimated by OLS using both the quarterly and yearly figures in Source 2.
Estimation 2: Quarterly GOV are estimated by multiplying the annual GOV values from Source 1 by the estimated quarterly shares from Estimation (1), from 1997.Q1 to 1999.Q4
Transformation 1: into Billion of Yuan
Transformation 2: into Real values by dividing it by CPI/100
Transformation 3: into Shares of GDP by dividing it by real GDP
Transformation 4: into Logs

OPEN (Openness: Real exports plus real imports in shares of real GDP)
Source: IFS database, IMF
Original data format: nominal quarterly values in millions of US dollars
Transformation 1: into billions of Yuan by using the nominal exchange rate of Yuan/USD from IFS
Transformation 2: into Real values by dividing it by CPI/100
Transformation 3: into Shares of GDP by dividing it by the real GDP
Transformation 4: into Logs

SURPLUS (Trade Surplus as a proxy for Terms of Trade)
Source: IFS database, IMF
Original data format: nominal quarterly exports minus imports in millions of US dollars
Transformation 1: into billions of Yuan by using the nominal exchange rate of Yuan/USD from IFS

Transformation 2: into Real values by dividing it by CPI/100
Transformation 3: into Shares of GDP by dividing it by the real GDP

NFA (Net Foreign Assets as a proxy for Capital Outflow)
Source: IFS database, IMF
Original data format: nominal quarterly values in billions of Yuan
Transformation 1: into Real values by dividing it by CPI/100
Transformation 2: into Shares of GDP by dividing it by real GDP
Transformation 3: into Logs

NEER (Nominal Effective Exchange Rate of Yuan)
Source: IFS database, IMF
Original data format: quarterly index

DAVIDSON INSTITUTE WORKING PAPER SERIES - Most Recent Papers

The entire Working Paper Series may be downloaded free of charge at: www.wdi.umich.edu

CURRENT AS OF 10/1/08

Publication	Authors	Date
No. 934: Yuan Real Exchange Rate Undervaluation, 1997-2006. How Much, How Often? Not Much, Not Often	Jeff Chen, Wende Deng & David Kemme	Aug 2008
No. 933: How Important Are Foreign Shocks in Small Open Economy? The Case of Slovakia	Roman Horváth and Marek Rusnák	Sept 2008
No. 932: Estimating Poverty for Indigenous Groups in Chile by Matching Census and Survey Data	Claudio A. Agostini, Philip H. Brown, and Andrei Roman	Aug 2008
No. 931: Is There Electoral Cycles In Globalization Process? Evidence From 78 Democratic Countries, 1975 – 2006	Krishna Chaitanya Vadlamannati	Sept 2008
No. 930: Lobbying, Corruption & Other Banes	Nauro Campos & Francesco Giovannoni	Sept 2008
No. 929: Do Elections Slow Down Economic Globalization Process In India? It's Politics Stupid!	Krishna C Vadlamannati	Aug 2008
No. 928: Impact Of Institutional Quality On Human Rights Abuses In Transition Economies	Krishna C Vadlamannati & Artur Tamazian	July 2008
No. 927: Do Choice & Speed Of Reforms Matter For Human Rights During Transition?	Krishna Chaitanya Vadlamannati	July 2008
No. 926: Socioeconomic, Institutional & Political Determinants Of Human Rights Abuses: A Subnational Study Of India, 1993 – 2002	Krishna Chaitanya Vadlamannati	July 2008
No. 925: Does the Entry Mode of Foreign Banks Matter for Bank Efficiency? Evidence from the Czech Republic, Hungary, and Poland	Ngoc-Anh Vo Thi & Dev Vencappa	July 2008
No. 924: Impact Of Economic Reforms On Poverty – Indian Experience	Krishna Chaitanya Vadlamannati	July 2008
No. 923: India & South Asia – Indian Economic Reforms & Direct Foreign Investments: How Much Difference Do They Make To Neighbors?	Krishna Chaitanya Vadlamannati	July 2008
No. 922: The Effects of Monetary Policy in the Czech Republic: An Empirical Study	Magdalena Morgese Borys and Roman Horváth	May 2008
No. 921: Goods Market Integration in Russia during the Economic Upturn	Konstantin Gluschenko	May 2008
No. 920: Labour Market Matching Efficiency In The Czech Republic Transition	Pablo de Pedraza	April 2008
No. 919: The Emerging Aversion to Inequality: Evidence from Poland 1992-2005	Irena Grosfeld and Claudia Senik	April 2008
No. 918: Exploring The Relationship Between Military Spending & Income Inequality In South Asia	Krishna Chaitanya Vadlamannati	Feb 2008
No. 917: Productive, Unproductive and Destructive Entrepreneurship: A Theoretical and Empirical Exploration	Arnis Sauka	Mar 2008
No. 916: MARKET RISK DYNAMICS AND COMPETITIVENESS AFTER THE EURO: Evidence from EMU Members	Juan Piñeiro Chousa, Artur Tamazian & Davit N. Melikyan	Feb 2008
No. 915: An Impact Analysis of Microfinance in Bosnia and Herzegovina	Valentina Hartarska & Denis Nadolnyak	Dec 2007
No. 914: Why are Optimistic Entrepreneurs Successful? An Application of the Regulatory Focus Theory	Ruta Aidis, Tomasz Mickiewicz & Arnis Sauka	Feb 2008
No. 913: Measuring Underground (Unobserved, Non-Observed, Unrecorded) Economies in Transition Countries: Can We Trust GDP?	Edgar L. Feige and Ivica Urban	March 2008
No. 912: On The Trade Balance Effects Of Free Trade Agreements Between The Eu-15 And The Ceec-4 Countries	Guglielmo Maria Caporale, Christophe Rault, Robert Sova & Ana Maria Sova	March 2008