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Structural Breaks and the Equilibrium Chinese Yuan/US Dollar Real Exchange Rate: A FEER Approach

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Abstract

This paper examines the equilibrium real exchange rate of the Chinese Yuan against the US Dollar within the framework of the FEER model. Quarterly data for the post-reform period 1982-2009 are used. We make three important contributions to the literature. First, we allow for endogenous structural breaks in all cointegration relationships. Second, our study highlights macroeconomic fundamentals that affect savings and investment and, hence, the sustainable current account in the medium-term. Third, we construct a unique set of quarterly data. We find structural breaks in all trade and the sustainable current account equations, with the break dates corresponding to important policy changes in China. The misalignment rates show that the real exchange rate was overvalued in most years until 2003, followed by undervaluation during 2004-2009. However, the average misalignment rates and revaluation required to correct this undervaluation are not as large as suggested by previous studies, with the undervaluation rate declining sharply in 2009. We further simulate misalignment rates using a sustainable current account of three percent. Our findings suggest such exogenous input leads to results biased towards larger undervaluation.

Key Words: Fundamental equilibrium exchange rate; Real CNY/USD; Structural breaks; Misalignments; China

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1. Introduction

The growing USA trade deficit with China has caused considerable debate among politicians and academics about China's international competitiveness and the value of its currency, Renminbi (RMB)[1]. A number of studies have addressed this subject by investigating the equilibrium real exchange rate between the Chinese Yuan and the US Dollar, with the majority showing substantial undervaluation in the real RMB since the middle of the 1990s[2].

In this paper we apply the Fundamental Equilibrium Exchange Rate (FEER) model which considers the whole economy and provides more information about the fundamental determinants of the equilibrium exchange rate than other approaches. Chueng *et al* (2010) argue that compared with other approaches, the FEER model is more informative to policy markers, though they are concerned that one may obtain different magnitude of misalignments depending on the exogenous input of norm or target current account in the medium-term. They believe that including determinants of investment and savings to obtain the target current account is more reliable. The third contribution of our study specifically addresses their concern.

Recent studies that have applied the FEER model to China include Jeong and Mazier (2003), Wang (2004), Wren-Lewis (2004a), Cline (2005, 2007) and Coudert and Couharde (2007). However, only Cline (2005, 2007) and Coudert and Couharde (2007) apply the model to the real bilateral CNY/USD exchange rate, and only for one or two years[3].

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[1] RMB is the name of the Chinese currency. Chinese Yuan is the unit of the currency. In the foreign exchange market, the exchange rate is measured as Yuan against other currencies (e.g. US Dollar).

[2] For a recent review of the empirical literature on China's equilibrium exchange rate using alternative models such as the PPP (Purchasing Power Parity), BEER (Behavioural Equilibrium Exchange Rate) and FEER (Fundamental Equilibrium Exchange Rate) models, see Cline and Williamson (2007) and Cheung *et al* (2010).

[3] To be more specific, Cline (2005) and Cline (2007) are for one year (2005 and 2007 respectively) and Coudert and Couharde (2007) is for two years (2002-2003).

We make three important contributions to the literature. First, the Chinese economy was subjected to major political and economic changes in recent decades. However, none of the previous studies has taken structural breaks into account. In this paper we allow for the presence of endogenous structural breaks in all cointegration equations using the Gregory and Hansen (1996) method.

Second, in order to increase the size of our sample and hence the power of the cointegration tests, we use for the first time a unique set of quarterly data for the post reform period, 1982-2009. In addition, trade parameters in previous papers are either based on a few years of observations, or on simplified calibrations[4]. In our study we estimate separately all the parameters of trade volume and price equations.

Third, previous FEER studies for China often use a "target" current account towards which the current account should move in the medium-term. The target is based either on the level of Chinese current account that is thought necessary to achieve global (especially the US) current account rebalancing (e.g. Cline, 2005, 2007) or on a simplified assumption of a normal current account (e.g. Wren-Lewis, 2004a; Coudert and Couharde, 2007)[5]. Assuming the sustainable current account to be a certain target level may seem feasible for a single year, but would not be applicable to longer periods as the sustainable current account evolves overtime. Our investigation of sustainable current account draws upon Chinn and Prasad (2003) and You and Sarantis (2008) who employ an approach that highlights medium-term macroeconomic fundamentals that determine savings and investment. This addresses the concern raised by Cheung *et al* (2010) mentioned earlier.

[4] For instance, FEER estimates of Coudert and Couharde (2007) and Wang (2004) are for 2002-2003 and 2000-2002 respectively; Wren-Lewis (2004a) use calibrated parameters in trade equations.

[5] To our knowledge, the only FEER studies that estimate the sustainable current account for China are Joeng and Mazier (2003) and Wang (2004). However, neither of these studies considers structural breaks. Second, parameters used by Joeng and Mazier (2003) are borrowed from regressions of an unspecified panel of 18 emerging markets, not from direct estimation of the China; parameters of Wang (2004) are subject to short term disturbance due to the short sample period 2000-2002.

The paper is organised as follows. Section 2 outlines the FEER model for China. Section 3 discusses the Gregory and Hansen (1996) cointegration test. Section 4 presents the empirical estimates for the trend and sustainable current accounts. Section 5 calculates the FEER for the bilateral CNY/USD real exchange rate and analyses the misalignments. Section 6 compares our results with previous studies and simulates misalignments using a 3% target sustainable current account. Section 7 draws conclusions.

2. The FEER Model for China

The Fundamental Equilibrium Exchange Rate (FEER), an equilibrium concept developed by Williamson (1983), can be calculated in two alternative ways. The first approach uses a complete macroeconomic model and generates the FEER as a solution. The second approach uses a partial equilibrium model (Driver and Wren-Lewis, 1998; Wren-Lewis, 2003, 2004a, 2004b; Barisone, Driver and Wren-Lewis, 2006). The partial equilibrium approach attempts to estimate part of the complete macroeconomic system and treats the rest as an exogenous input. The motivation is mainly simplicity and clarity[6]. There are three steps in estimating the FEER using the partial equilibrium approach. The first step is to estimate the trend current account that is consistent with the internal balance. The second step is to calculate the sustainable current account—the current account that matches medium-term structural capital flows. The trend current account in the first step is estimated keeping the real exchange rate unchanged. However, the real exchange rate must move to clear the balance of payments and simultaneously drive the trend current account to match the

[6] The model rules out any feedback from the estimated exchange rate to exogenous variables. If there is feedback from the real exchange rate to trend output or savings and investment decisions, there may be inconsistencies between the off-model assumptions and the solution for the real exchange rate. However, Driver and Wren-Lewis (1999) examine the sensitivity of FEERs to feedback from the real exchange rate to output and conclude that the effects are relatively small.

sustainable current account. The third step is to calculate the FEER that delivers this match. As the trend current account is a function of FEER and the sustainable current account is known, we solve for FEER by equating the former with the latter.

2.1. The Real Exchange Rate

Following Barisone, Driver and Wren-Lewis (BDW thereafter) (2006), we define the real exchange rate, E, as

$$E = N \times \frac{WXP}{P} \tag{1}$$

where N, WXP and P denote, respectively, the nominal exchange rate of the Chinese Yuan against the US Dollar (CNY/USD), world export prices (in USD) and domestic output price (in CNY). An increase in E implies depreciation of the real RMB and *vice versa*.

2.2. Trend Current Account

The trend current account is the current account that is consistent with internal balance. We estimate the trend current account following BDW (2006) where the trend current account has three components: the trend trade balance, trend interest, profits and dividends (IPD) flows and the trend net transfer.

Trend Trade Balance: the trend trade balance is endogenous and is different from the actual trade balance in two perspectives. First, the actual trade balance contains the effect of temporary shocks while those shocks are stripped out in the trend trade balance. Trade balance is called the predicted trade balance when shocks are removed. Secondly, the trend trade balance is the balance that would have prevailed if output equals potential output (zero output gap). The derivation of trend trade balance involves estimation of trade volume and trade prices equations for exports and imports respectively.

Following BDW (2006), the predicted real net trade (RNT) is determined by export volume (X), real export price (RXP), import volume (M) and real import price (RMP)[7] as follows:

$$X = X(WT, XCOM) \Rightarrow X = X(\underset{+}{WT}, \underset{+}{E/RXP}) \qquad \textit{export volume equation} \quad (2)$$

$$RXP = RXP(\underset{+}{E}, \underset{+}{RCXP}) \qquad \textit{real export price equation} \quad (3)$$

$$M = M(Y, MCOM) \Rightarrow M = M(\underset{+}{Y}, \underset{-}{RMP}) \qquad \textit{import volume equation} \quad (4)$$

$$RMP = RMP(\underset{+}{E}, \underset{+}{RCMP}) \qquad \textit{real import price equation} \quad (5)$$

$$RNT = X(WT, E/RXP)RXP(E, RCXP) - M(Y, RMP)RMP(E, RCMP) \quad (6)$$

In trade volume equations (2) and (4), WT, $XCOM$, Y and $MCOM$ denote world export volume, export competitiveness, domestic real output and import competitiveness respectively. As discussed by BDW (2006), the trade volume equations (2) and (4) embody the traditional "demand curve" approach (i.e. Goldstein and Kahn, 1985). Real domestic output of China (Y) measures the total demand for imports which captures the impact of the domestic activity on China's imports, while the world export volume (WT) measures the total demand for Chinese exports which captures the impact of the world's activity on China's exports. Export competitiveness is measured as the world export price relative to the export price of China. An increase of $XCOM$ implies China's export price is relatively lower than world export

[7] Details on the specification of the trade volume and price equations can be found in Wren-Lewis (2003, 2004a) and BDW (2006). Some studies further divide trade into trade in goods and trade in services (i.e. Hristov, 2002). Due to limited data availability for China, we use data for aggregate exports and imports.

price. It makes Chinese exports more competitive in the world markets, which leads to higher export volume. Import competitiveness is measured as China's import price relative to its domestic price. An increase of $MCOM$ implies imports become relatively more expensive than domestic goods, and hence leads to lower import volume[8].

Equations (3) and (5) show that real export and import prices depend on real commodity prices (i.e. real commodity export ($RCXP$) and import price ($RCMP$) respectively) and the real exchange rate. Real trade prices are derived by dividing the nominal trade price by domestic output price. Nominal trade prices depend on commodity prices, domestic output prices and world export prices. See Appendix A for detailed steps of derivation.

Using the estimated coefficients from equations (2)-(5) and the actual values of the variables, we calculate the predicted real trade balance (equation (6)) that is not affected by the shocks. To obtain the trend current account, the internal balance condition (zero output gap) must be satisfied. To achieve such a condition, we apply the HP (Hodrick-Prescott)-filter to the actual value of domestic real output, Y. By replacing the actual value of Y with its smoothed values in equation (6), we obtain the real trend trade balance $\overline{RNT}$.

Trend IPD Flows: following BDW (2006), we regard IPD flows as exogenous while taking into account the effect of exchange rate revaluation and smoothing the series using the HP-filter. To take into account the effect of currency revaluation, Hristov (2002) models the currency revaluation as the gap between FEER and actual real

[8] Export and import competitiveness can be rearranged as $XCOM = \frac{WXP}{XP} = \frac{WXP}{P/N} \times \frac{P/N}{XP} = E/RXP$ and $MCOM = RMP = \frac{MP}{P/N} = \frac{WXP}{P/N} \times \frac{MP}{WXP} = E/(WXP/MP)$ respectively. RXP and RMP denote real export price and real import price and are measured as export and import price divided by domestic price of China respectively.

bilateral exchange rate divided by the actual real exchange rate and incorporates it into the IPD flows[9]

$$IPD = \left(1 + \left(FEER - E\right)/E\right)\left(IPDC - IPDD\right) \tag{7}$$

where $(FEER - E)/E$ measures the revaluation effect, *IPDC* and *IPDD* denote overseas assets held by domestic residents and domestic assets held by overseas residents, respectively. To obtain the smoothed IPD flow, we apply the HP-filter to $(IPDC - IPDD)$

$$\overline{IPD} = \left(1 + \left(FEER - E\right)/E\right)\overline{\left(IPDC - IPDD\right)} \tag{8}$$

with the smoothed series denoted by " $^{-}$ ".

Trend Current Account: net transfer is regarded as exogenous and it is smoothed by the HP-filter to get the trended value. The trend current account is the sum of trend trade balance, trend IPD flows and trend net transfer. Differences between the actual and trend current account generally reflect either cyclical movements in output, or persistent deviations in actual trade balance (trade volumes or prices) from their predicted levels.

2.3. Sustainable Current Account

There are two approaches for estimating the sustainable current account. One derives measures of sustainable (structure) capital flows, which finance current account imbalances (Williamson and Mahar, 1998). Another approach equates the current account to the savings minus investment in the economy. This methodology was developed by Masson (1998) and applied by Debelle and Faruqee (1998) to industrial countries and by Chinn and Prasad (2003) to developing countries.

[9] In Hristov (2002), the net IPD flow is measured as $IPD = \left(1 + \rho\left(\left(FEER - E\right)/E\right)\right)\left(IPDC - IPDD\right)$, with ρ measured the proportion of the revaluation effect and is it assumed that $\rho = 1$. For simplicity, in our study we also assume that the proportion of the revaluation effect equals unity.

Chinn and Prasad (2003) identify a comprehensive list of macroeconomic determinants of current account for developing countries based on an extensive review of medium-term savings and investment behaviour. Employing an extended NATREX model for China, You and Sarantis (2008) also highlight similar macroeconomic fundamentals for savings and investment in a longer term. The group of variables in Chinn and Prasad (2003) includes government budget balance to GDP ratio (GOVBGDP), net foreign assets to GDP ratio (NFAGDP), relative young dependency ratio (RELDEPY), relative old dependence ratio (RELDEPO), financial deepening (FDEEP), volatility of terms of trade (TOTSD), degree of openness to international trade (OPEN), stage of development factor that is captured by relative per capita income (RELY) and its square (RELYSQ) and average GDP growth (YGR). A large number of developed and developing countries are included in Chinn and Prasad (2003), but China is not one of them. More recently, Chinn and Ito (2008) include China in an emerging market group and examine these determinates identified by Chinn and Prasad (2003) for the group during 1971-2004. However, in most experiments China seems to be an outlier.

We follow Chinn and Prasad (2003) and You and Sarantis (2008) in our specification of sustainable current account. It is the first time we construct and investigate this unique group of economic fundamentals specifically for China. All relative variables are constructed compared to the world[10]. Equation (9) presents the list of determinants and their expected signs for the sustainable current account ($SCAY$)[11].

[10] Chinn and Prasad (2003) explain that they did not use terms of trade in their cross-sectional and panel analysis as terms of trade is an index. They used volatility of terms of trade instead. In our time series study, we employ term of trade for China and construct the relative terms of trade (RTOT) as term of trade of China relative to the world. Please see Appendix B for detailed measurement of RTOT.

[11] For detailed discussions on economic theories that rationalise how these determinants affect the current account as well as their expected signs, please refer to Chinn and Prasad (2003) and You and Sarantis (2008).

$$SCAY = S - I = SCAY(Z)$$

$$\underset{}{Z} = (\underset{+}{GOVBGDP}, \underset{+}{NFAGDP}, \underset{-}{RELDEPY}, \underset{-}{RELDEPO}, \underset{+}{FDEEP}, \underset{+}{RTOT}, \underset{-}{OPEN}, \underset{+}{RELY}, \underset{-}{RELYSQ}, \underset{+}{YGR}) \quad (9)$$

3. Gregory and Hansen (1996) Cointegration Test with Structural Break

Conventional cointegration tests cannot accommodate structural changes. Therefore, we employ the Gregory and Hansen (1996) (G-H thereafter) cointegration method, where a break is allowed at a single unknown time during the sample period. Specifically, the G-H method can detect cointegration relationships when there is a level shift (Model C), a level shift with trend (Model C/T) or a regime shift where intercept and slope coefficients change (Model C/S). The specifications of these three models are as follows:

Model C: level shift

$$y_{1t} = \mu_1 + \mu_2 \varphi_{t\tau} + \alpha^{\mathsf{T}} y_{2t} + e_t,\ t = 1, \ldots, n \qquad (10)$$

where y_{1t} is a vector of the dependent variable, y_{2t} is an m-vector of independent variables and is $I(1)$, e_t is the error term and is $I(0)$, μ_1 represents the intercept before the shift, μ_2 denotes the change in the intercept at the time of the shift, α denotes the slope coefficients, n is the number of observations. $\varphi_{t\tau}$ is a dummy variable defined as:

$$\varphi_{t\tau} = \begin{cases} 0 & if \quad t \leq [n\tau], \\ 1 & if \quad t > [n\tau], \end{cases} \qquad (11)$$

where the unknown parameter $\tau \in (0,1)$ represents the timing of the change point and [ ] represents the integer part.

Model C/T: level shift with trend

$$y_{1t} = \mu_1 + \mu_2 \varphi_{t\tau} + \beta t + \alpha^{\mathsf{T}} y_{2t} + e_t,\ t = 1, \ldots, n \qquad (12)$$

where β is the coefficient of the time trend t.

Model C/S: regime shift

$$y_{1t} = \mu_1 + \mu_2\varphi_{t\tau} + \alpha_1^{\mathrm{T}} y_{2t} + \alpha_2^{\mathrm{T}} y_{2t}\varphi_{t\tau} + e_t,\ t = 1, \dots, n \tag{13}$$

where α_1 denotes the slope coefficients before the break and α_2 denotes change in the slope.

The G-H method tests for the null hypothesis of no cointegration against the alternative of cointegration in the presence of a possible structural change represented in the three models above. Three alternative test statistics of unit root, namely ADF, Zt and Zα test, are carried out on a series of successive residuals that are corresponding to all possible break points considered over the whole sample period. The location of the minimum value of the statistics indicates the break date. In our study, breaks are chosen based on the Zt test statistics as Gregory and Hansen (1996) suggest that Zt is the best in terms of size and power. The statistics of G-H methods do not follow standard distribution and hence standard critical values for residual based cointegration tests are not applicable. In our paper we use critical values constructed by Gregory and Hansen (1996) using the response surface[12].

4. Empirical Results

As argued by BDW (2006), the FEER describes medium-term equilibrium, and hence the concern is not the short run dynamics of trend and sustainable current account equations, but their longer term properties. Therefore, we employ the cointegration method to test for the long run properties of the equations. In addition we allow for structural breaks within the cointegration relationships. We also look at the adjustment

[12] Another cointegration test that allows for structural breaks is the Johansen *et al* (2000) method, which can allow up to two breaks. However, the break dates are not endogenously tested but treated as known, and the breaks are restricted in the intercept and/or trend only. In contrast, the G-H method searches for break at unknown time and can also allow for breaks in the slope coefficients. Therefore, in these two perspectives, we believe G-H methods could be more accurate as well as more flexible.

factor in the error-correction model to evaluate the stability of the equations. We employ quarterly data and the sample period is 1982q1-2009q4. A detailed description of the data is given in Appendix B.

Before we carry out the cointegration estimation, we apply the ADF (augmented Dickey-Fuller) unit root test in order to test for the stationarity of the variables. The number of lags in the ADF test is chosen using the general to specific procedure suggested by Campbell and Perron (1991). We also report ADF statistics with lags chosen by the modified AIC proposed by Ng and Perron (2001). The ADF statistics based on two alternative ways of choosing lags, reported in Table 1, suggest all variables follow an $I(1)$ process except RELY, RELYSQ and YGR.

4.1. Trend Current Account

We use the G-H cointegration tests which can accommodate one endogenous structural break for all four trade equations. We examine all three models (i.e. C, C/T and C/S). G-H test statistics are presented in Table 2 and corresponding cointegration parameters are reported in Table 3.

Export Volume Equation: in all three models, the null of no cointegration is rejected. In model C/S, the adjustment factor is negative but insignificant. Note that model C/T includes a trend while model C does not. The trend in model C/T is highly significant[13]. In addition, the adjustment factor for model C/T is at 1% significance level compared with only 10% for model C. Therefore, we choose model C/T for the export volume equation. All coefficients are highly significant in model C/T. The break date is 1986q1, shortly after the termination of Internal Rate of Trade Settlement in 1985. We observe a negative level shift after the break, which may

[13] Note that a trend is often included in trade volume equations in FEER model (e.g. BDW (2006) and Wren-Lewis (2004b)).

reflect the negative impact of the abolishment of the internal rate as the internal rate system was initially established to stimulate exports. The coefficients of world trade (*WT*) and export competitiveness (*XCOM*) are both positive and significant. Our estimate of the world demand elasticity is 1.4478 and sits at the lower range of estimates reported by previous studies[14]. However, our relative export price elasticity is 1.6284, higher than those found by other studies[15]. Our results highlight the importance of price competitiveness in boosting China's export volume.

Import Volume Equation: in all three models, the null of no cointegration is rejected. In models C and C/S, coefficients of import competitiveness (*MCOM*) are wrongly signed (positive) and insignificant. Therefore, we focus on the C/T model where a break is allowed in level with the presence of a time trend. There is a positive trend and all variables are correctly signed and significant. Interestingly, the break date is 1994q3, shortly after the dual exchange rate (swap rate and official rate) system was terminated in early 1994. There is a negative level shift. After Deng Xiaoping's South Tour in 1992 encouraging Foreign direct investment (FDI), FDI started to increase at a fast pace. The abolishment of the dual rate system in 1994 further stimulated FDI to China and created a peak of around 6.2% of GDP. Part of the FDI was channelled into manufacturing production targeted for import substitution. Lemoine (2000) finds that foreign invested enterprises' production accounts for a more important part than imports in the supply of Chinese domestic demand. The negative level shift after 1994q3 may capture such an import substitution effect generated by the FDI. The income elasticity and price competitiveness elasticity are 0.8274 and -0.1415

[14] Cheung *et al* (2009) reviewed previous studies and find the world demand elasticity for China's exports ranging from 0.26 to as high as 10. Note that these studies use bilateral China-US trade data. Two recent studies which are not reviewed by Cheung *et al* (2009) are Aziz and Li (2008) and Shu and Yip (2006). Aziz and Li (2008) use China's total trade volume data and Shu and Yip (2006) use data of China's trade with the US, the EU and Japan. They find the elasticity to be 3.8 and 4.27 respectively.

[15] Studies reviewed by Cheung *et al* (2009) generate price elasticity for China exports ranging from 0.2 to 1.3. The elasticity find by Aziz and Li (2008) and Shu and Yip (2006) is within this range.

respectively. This implies that China's demand for imports is much more income elastic than price elastic. Our income elasticity is within what has been reported by previous studies[16], while the relative import price elasticity is much lower than estimates reported by previous studies[17].

The sum of the absolute values of export and import competitiveness is greater than unity (1.7699), mainly due to the high export prices elasticity. It suggests that the Marshall-Lerner condition is satisfied in China, and hence currency devaluation can have a positive effect on the trade balance.

Real Export Price Equation: the null of no cointegration is rejected in all three models. However, in models C and C/S, coefficients for real commodity export price (*RCXP*) are negative. Therefore, we choose model C/T. The break date is 1990q1. All coefficients are correctly signed and significant. There is a slight positive time trend and a positive level shift. The coefficients of real commodity export price and real exchange rate capture the share of commodity (homogenous) and manufacture (non-homogenous) exports respectively. Their estimates are 5.6% and 93.4% respectively, the sum of both estimates is very close to unity. Decomposing the coefficient of real exchange rate using equation (A.3) in Appendix A, we can obtain γ=0.93. Therefore, 93% of the export price is determined by the world export prices whilst only 7% is determined by the domestic output price (see Table 6). This implies that Chinese export prices are determined mainly by world export prices[18].

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[16] Studies reviewed by Cheung *et al* (2009) find income elasticity for China's imports ranging from 0.7 to 2.3. The elasticity find by Aziz and Li (2008) and Shu and Yip (2006) is within this range.

[17] Studies reviewed by Cheung *et al* (2009) find price elasticity for China's imports ranging from 0.42 2.04. Aziz and Li (2008) find it to be within the range but Shu and Yip (2006) find it to be 2.29.

[18] Studies investigating China's trade elasticities often use trade value data rather than trade volume and price data separately. Studies that estimate both trade volume and price for China are rare. As far as we know, Dées (1999) estimates China's annual trade price equation for period 1984-1995. However, Dées (1999) does not take into account structural break, and the sample period is relatively short. Dées (1999) finds that 72% and 28% of China's export prices are determined by world export prices and domestic price level respectively. Our study finds a much stronger impact of world export prices on China's export prices of 93%.

Real Import Price Equation: The null of no cointegration is rejected in all three models. However, in model C, the level shift was insignificant. In model C/T, the real commodity import price (*RCMP*) is insignificant. In model C/S, although RCMP is insignificant before the break, it turns to become significant after the break. Therefore, we choose model C/S where a regime shift is allowed. The break date is 1987q1. Before the break, the coefficient for real exchange rate is near unity and commodity share is negative but insignificant. This may reflect the government's emphasis on importing technology and equipment from the West during this period (Wu and Mao, 1993), which had a substantial upward impact on manufacture imports. More importantly, after 1987q1, the commodity share was increased to 15.6% and the coefficient of exchange rate was reduced to 85.6%.

We decompose the coefficient of real exchange rate using equation (A.4) in Appendix A and obtain ϕ=0.83. Therefore, 83% of import prices is determined by world export prices, contrasting to only 17% of that is determined by the domestic output price (see Table 6)[19]. Our estimates of export and import prices show that they are largely determined by world export prices, thus supporting the exogeneity of the terms of trade for China.

The adjustment factors for all equations are presented in the last row of Table 3. All of them are negative. They are also significant in the export volume and import volume equations. Although the adjustment factors of trade price equations are insignificant, they are nevertheless negative, and the stability of trade volume will ensure the long-term stability of the net trade.

[19] Dées (1999) finds that 87% and 13% of China's import prices are determined by world export prices and domestic price level respectively. Our study finds a weaker impact of world export prices on China's import prices of 83%. One the other hand, the impact of domestic price level on China's import prices is stronger (17%).

Trend Current Account: based on the coefficients in Table 3 and actual values of the variables, we are able to compute the predicted trade volumes and prices and therefore obtain the predicted exports and imports. We apply the HP-filter to output (real GDP) to obtain potential output. By imposing the condition of internal balance we obtain the trend net trade. In order to tackle the end-point problem of HP-filter (see Giorno *et al*, 1995), we extend our real GDP series until 2015 using real GDP projections from the IMF World Economic Outlook[20]. Following BDW (2006), the world trade volume is also smoothed using the HP-filter. Projections of world trade volume until 2015 are obtained from the Global Forecasting Service of the Economist Intelligence Unit. We also apply the HP-filter to projected net IPD flows and net transfers to obtain the trend net IPD flows and trend net transfers[21]. The sum of the trend net trade, trend net IPD flows and trend net transfers yields the trend current account. The latter is plotted against the actual value (both as percentage of GDP) in Figure 1. Data in all graphs are annualised (average of four quarters).

4.2. Sustainable Current Account

RELY, RELYSQ and YGR are excluded as they do not follow an $I(1)$ process[22]. Initially, we included RTOT, RELDEPO, RELDEPY, OPEN, GOVBGDP, FDEEP and NFAGDP in one cointegration equation. In model C, the null of no cointegration is rejected with a break date of 1986q1. However, when NFAGDP is included, the estimated sustainable current account is unrealistically high (around 11% in 2009

[20] BDW (2006) also extend their sample period from 1997 to 2002 using projections to tackle the end point problem of the H-P filter.

[21] The World Bank Main Economic Indicators (MEI) provide projections of current account and trade balance (export minus import in goods and service) for China until 2015. The gap between these two series gives the projection of the sum of net IPD flows and net transfers. The projected sum is then divided according to the average annual share of net IPD flows and net transfers during 1982-2009.

[22] We found RELY, RELYSQ and YGR follow I(2), I(3) and I(0) process respectively. First difference of RELY follows an I(1) process. We experimented with it in the cointegrations but it was insignificant in all cases.

when we use data from IFS or extended series of Lane and Milesi-Ferretti (2007)). In addition, the coefficient is unfeasibly high (0.24 using data from IFS or 0.34 using the extended series of Lane and Milesi-Ferretti (2007))[23]. Therefore, we exclude this variable in the cointegration and re-estimate the break date. In model C, the null of no cointegration is rejected with a break date of 1984q3, with FDEEP and RELDEPO wrongly (positive) signed and insignificant. In all experiments, RTOT, RELDEPY, OPEN and GOVBGDP remain highly significant. Thus we keep these four variables in our final sustainable current account equation and re-estimate the break date[24].

The G-H statistics are presented in Table 4. The null of no cointegration is rejected in all three models. Break dates are all in 1992. In model C/S, the level shift of unrealistically high and most variables become wrongly signed if their coefficients are allowed to change. In model C/T, the incorporation of a trend leads to excessively high level of sustainable current account and several variables become wrongly signed and/or insignificant. Therefore, we adopt model C as our final equation. The adjustment factor of the error correction model is negative and significant. The level shift is negative and occurs in 1992q2, dividing the whole sample period into two sub-samples of 1982q1-1992q2 and 1992q3-2009q4. Deng Xiaoping's South Tour in early 1992 established the further reform and opening up direction of "setting up a socialist market economy in China". This guideline stimulated FDI to China by helping to create a better investment environment for Foreign Invested Enterprises (FIEs). The

[23] From a balance of payment point of view, current account is the sum of net trade plus return on a country's stock of NFA (e.g. interest income). Having a 24% or 36% rate of return is unfeasible. From another perspective, Chinn and Prasad (2003) argue that for growing economies, the existence of perpetual non-zero current account balances is consistent with a stable NFA/GDP ratio. The steady-state relationship is then given by CAY=g*NFA, where g is the rate of growth of nominal GDP. Again it is not feasible to have a growth rate of 24% or 36% in nominal GDP of China.

[24] It is worth mentioning that in Chinn and Prasad (2003), RELY, YGR and RELDEPO are insignificant in both cross-sectional and panel regressions for developing countries. NFAGDP is only significant in panel regression for developing countries. Although Chinn and Prasad (2003) found FDEEP to be significant determinants of sustainable current account for developing countries, in our study for China this variable is insignificant.

negative level shift after the break in 1992 reflects the large inflow of foreign direct investment attracted by FDI favourable policies.

Estimates of the cointegration equation are shown in Table 5. Relative terms of trade have a positive and significant coefficient. This in line with the HLM hypothesis (Harberger, 1950; Laursen and Metzler, 1950) which predicts a positive relationship between exogenous changes in terms of trade and national savings, through consumption smoothing behaviour. Some recent studies examining and supporting the HLM effect include Ahmed and Park (1994), Mendoza (1995) and Otto (2003).

Relative young dependency ratio has a negative coefficient. A higher relative dependency ratio of the young raises consumption and lowers the saving ratio. Therefore, it is negatively related to the current account. Chinn and Ito (2008) find a similar negative demographic effect on the current account for an emerging market group (EMG) that includes China over the period 1971-2004.

Chinn and Prasad (2003) argue that more open economies are more attractive to foreign capital. In particular, they find that for developing countries, openness is positively related to investment, but not to savings, which leads to a negative relationship between openness and current account. China's exports have benefited substantially from its openness in trade and this has increased the income of Chinese households. The latter has led to more savings rather than greater demand for imports. The strong saving habit of the Chinese household could be explained by China's underdeveloped pension and medical care system. Therefore, openness also has a positive impact of savings in China. Our results suggest that this positive impact is stronger on savings than on investment, and hence openness has a positive relationship with current account[25].

Government budget balance has a positive coefficient. A variety of models predict such a positive coefficient over medium-term. For instance, using the overlapping generation model, Blanchard (1985) rejects Ricardian equivalence and suggests that an increase in government budget balance would lead to higher national savings, and consequently improves the current account. This relationship is expected to be stronger in China where liquidity constraint is still relatively tight and propensity to saving is relatively high. Our empirical results confirm this positive relationship between government budget balance and current account. Interestingly, Chinn and Ito (2008) also report a similar positive relationship for the EMG.

4.3. Sustainable, Trend and Actual Current Account

Based on the coefficients in Table 5 and HP-filtered fundamentals, we obtain the sustainable current account to GDP ratio (SCAY). As explained in Section 4.1., in order to tackle the end-point problem of HP-filter, we extend the four significant variables (i.e. RTOT, RELDEPY, GOVBGDP and OPEN) until 2015 using projections from the World Bank Main Economic Indicators, Country Statistical Profile of OECD, and the IMF Word Economic Outlook. The annualised SCAY is plotted against the trend (TCAY) and actual (CAY) current accounts (all measured as a percentage of real GDP) in Figure 1.

TCAY varied around balance within a narrow band of -1.5% — +1.5% of GDP until 1994. In 1995, TCAY increased to 2.8% but was soon dragged down by the onset of the Asian financial crisis in 1997. The TCAY was also relative low in early 2000, due

[25] From another perspective, Lane (2000) postulates that a higher degree of trade openness may raise output volatility, which calls for the need to accumulate substantial net foreign assets for the purpose of income smoothing and risk diversification by incurring current account surplus.

partly to the slowdown in the growth rate of the US and other major developed economies[26], and partly to China's WTO membership commitment at reducing tariff and non-tariff barriers. After 2003, the TCAY recovered and picked up strongly until 2008. The export price competitiveness had increased considerably at an average annual rate of 5.7% during 2003-2008. The stable growth rate of the world economy also contributed to the rapid increase in TCAY. However, the TCAY dropped sharply to 6.5% in 2009, due to a dramatic decrease in world demand (as a result of the global financial crisis) and loss in export competitiveness (due to 12% appreciation in the real exchange rate).

There was a negative level shift in SCAY in 1992. As discussed earlier, the shift probably reflects the large amount of capital inflow attracted by China's FDI favourable policies after Deng's Southern Tour in early 1992. As the economic fundamentals evolve, such as the steady decline in young dependency ratio and increase in openness ratio, the SCAY has been increasing gradually since 1992 but remained below 2.5% until 2000. SCAY has been growing at a slightly faster pace since 2001 and peaked at 6.5% in 2006. In the last three years of the sample period (2007-2009), SCAY started to fall due to large declines in OPEN and GOVBGDP and a slower decline in RELDEPY. Nevertheless, the SCAY still stayed at a relatively high level during 2007-2009 with an average of 5.1% of GDP. China's current account surplus can be maintained providing some of China's main trade partners can sustain current account deficits. For instance, during 2004-2008, the US ran an average current account deficit of 5.4%, although it declined to 2.7% in 2009, and the US has been running persistent current account deficits since 1992.

[26] For instance, the real GDP growth rate of the US declined from 4.8% and 4.1% in 1999 and 2000 respectively to 1.1% and 1.8% in 2001 and 2002 respectively. Data are collected from *IFS*.

5. The FEER and Misalignments

The trend current account was estimated by treating the real exchange rate as exogenous. However, the real exchange rate must move to clear the balance of payments and simultaneously drive the trend current account to match the sustainable current account. The third step is to calculate the FEER that delivers this match. As TCAY is a function of FEER and SCAY is known, we solve for the FEER by equating TCAY to SCAY. Figure 2 plots the FEER against the actual real exchange rate, while Figure 3 exhibits the misalignment rates[27].

As we can see from Figure 1, since the early 1990s the SCAY was above TCAY until 2003 (except slightly under in 1995), and the reverse is true during 2004-2009. Such a relationship between TCAY and SCAY suggests that depreciation and appreciation for the real exchange rate of the RMB were needed during the periods 1991-2003 and 2004-2009 respectively, to match TCAY with the SCAY.

Since the unification of official and swap rate in 1994[28], the bilateral CNY/USD real exchange rate has exhibited a small but continuous trend of appreciation from 11.8 in 1994 to 6.4 in 2009, a cumulative appreciation of 46.0%. The real exchange rate of RMB was overvalued consecutively from 1994 until 2003, except one year of slipping back to moderate undervaluation in 1995. The largest overvaluation occurred during China's early WTO access years of 2001-2002. The trend current account was dragged down due to declining in world imports demand and fast growing domestic imports. The second largest overvaluation occurred shortly after the onset of the 1997 Asian financial crisis. It was mainly due to low trend current account led by sluggish

[27] ADF tests show that the misalignment rates in Figure 3 are stationary at 5%.

[28] Before 1994, the nominal CNY/USD rate had been artificially depreciated many times. In particular, between 1982 and 1993, the nominal rate was depreciated against the USD by over 200% from 1.89 to 5.76 whilst the USD appreciated against China's major trade partners (except Japan and Singapore) at the same time. We observe overvaluation in 8 out of 12 years during this period. The 4 years of undervaluation occurred in early 1980s.

world imports. In addition, China's export competitiveness was also dampened as the RMB remained strong whilst other Asian currency depreciated.

Meanwhile, as the economic fundamentals evolved, the sustainable current account increased gradually from 2.0% of GDP in 1994 to 4.7% in 2003. This relationship between the trend and sustainable current accounts required the RMB real exchange rate to depreciate, or in other words, indicates that the RMB was overvalued in real terms. The average overvaluation during 1994-2003 was 19.9%. During the two large overvaluation periods, i.e. 2001-2002 and 1997-1999, the RMB was overvalued on average by 30.0% and 28.1% respectively.

During the last six years of our sample period (2004-2009), we find six consecutive years of undervaluation. While the sustainable current account increased slightly from 5.7% in 2004 to 6.5% in 2006 and then declined to 4.1% in 2009, the trend current account rose sharply due to higher world import demand during 2004-2008 and only dropped in 2009. The widening gap between trend and sustainable current account indicates sizeable and increasing undervaluation of the RMB in real terms during 2004-2008. Despite 15.5% cumulative appreciation in the real CNY/USD exchange rate during 2004-2008, the average rate of undervaluation was 30.8%. The undervaluation peaked in 2008 at 47.4%. In 2009, the gap between sustainable and trend current account narrowed considerably due to a much faster decline in the latter. Consequently, the magnitude of undervaluation dropped dramatically to 16.8% in 2009, which implies an average undervaluation of 28.5% over the period 2004-2009.

We convert the misalignments to revaluation rates required. The average revaluation required in the bilateral CNY/USD real exchange rate was 22.0% during 2004-2008, with a peak of 31.7% in 2008. However this was reduced significantly to 14.3% in 2009 (see Table 7).

6. Comparison with Previous Studies

In their review of FEER studies analysing the bilateral CNY/USD real exchange rate, Cline and Williamson (2007) find that previous studies show the RMB to be undervalued against the USD in real term during 2001-2007, with the average appreciation needed to eliminate undervaluation being 35%. In contrast, we found the bilateral CNY/USD real rate was overvalued from the early 1990s to 2003. We do find substantial undervaluation for the period 2004-2009, but the average required revaluation rate is 20.7%, considerably lower than the mean of previous studies. Also we observe a sharp decline in required revaluation in 2009 (to 14.3%)

Previous FEER papers for China use trend current account ranging from 2.1% (i.e. Wang, 2004) to 6.3% (i.e. Cline, 2007) during 2000-2007. Our study finds the trend current account was negative between the onset of Asian financial crisis in 1997 and China's WTO access year of 2001 with an average of -0.7% of GDP. This contrasts with all previous studies. In addition, during 2004-2008, we find a trend current account of 10.8% on average, higher than any previous studies. Even when the trend current account dropped to 6.5% in 2009, it is still higher than previous values. In our paper we estimate all parameters in trade volumes and prices equations separately and account for structural breaks. We therefore believe that our trend current account estimates are more reliable.

Typical FEER studies assume certain levels of current account as targets towards which the trend current account should adjust in the longer term. Various levels of sustainable current account have been used as targets for China, ranging from -2.8% (i.e. Coudert and Couharde, 2007) to 3.1% (i.e. Wang, 2004). Our study seeks to answer this question by using macroeconomic fundamentals that determine saving and investment in the longer term, as it is also stressed by Cheung *et al* (2010). In addition, we allow for endogenous structural breaks in the current account equation. We found the sustainable current account to be on average 3.7% during 2001-2003, and 5.7% during 2004-2009, higher than those assumed by previous studies.

In a recent update based on the FEER model, Cline and Williamson (2010) find an undervaluation of around 40.2% in March 2009 and only slightly larger in December 2009. However, Cline and Williamson (2010) use a projected current account of 10.6% for 2012 (obtained from the IMF) as the trend current account in 2009. This is much higher than the actual current account surplus of around 6% in 2009. Thus the authors point out that this undervaluation may be overstated. In contrast, our estimate of 6.5% trend current account in 2009 seems much more realistic[29].

Cheung *et al* (2010) find 50% of undervaluation in the CNY/USD real exchange rate for 2008 using the PPP model and 67% for January 2010 when they use the Big Mac index. The authors also report a recent update from Goldman Sachs (O'Neill, 2010) based on the BEER model that suggests an undervaluation of only 2.7% in 2009q4. However, Cheung *et al* (2010) point out misalignments derived using the PPP model change according to judicious choice of sample period. They also criticise the BEER approach for being ad hoc statistical and its empirical specification for lacking the foundation of an economic model.

To further assess the sensitivity of our results to the choice of sustainable current account, we simulate FEER and revaluation needed for the last six years (2004-2009) using a target of 3%[30]. We find that the revaluation needed has increased to an average of 38.9% during 2004-2008, with a peak of 43.8% in 2007, compared with an

[29] Cline and Williamson (2010) use a sustainable current account of 4% for 2009, which is higher than in all previous studies but still lower than our estimate.

[30] We choose 3% in our simulation as it is at the high end of target current account used by previous studies. Naturally, lower targets (e.g. 1% or -1%) will generate higher misalignment rates on undervaluation side.

average of 20.7% for the same period and a peak of 31.7% in 2008 found using our original estimates. For year 2009, the required revaluation increases to 20.9% compared with our original estimate of 14.3%.

7. Conclusions

Our study investigates the equilibrium CNY/USD real exchange rate using the FEER model. We examine a complete set of trade equations for China and we investigate the sustainable current account using an approach that highlights the effects of macroeconomic fundamentals on savings and investment in the medium-term. Another important contribution is that we allow for endogenous structural breaks in all cointegration equations.

The main empirical findings are as follows. First, after accounting for endogenous structural breaks, we found cointegration relationships for all trade equations and for the sustainable current account, which supports the theoretical relationships in the FEER model. Interestingly, the dates for the structural changes correspond to important policy changes in China. For trade equations, structural changes echo events such as the end of internal rate of trade settlement in the mid-1980s and the termination of the dual exchange system in 1994. The sustainable current account experienced the structural change in 1992 when larger capital inflows were attracted by FDI favourable policies stimulated by Deng's Southern Tour in early 1992.

Second, estimates of the trend current account suggest that both higher world demand and improvements in price competitiveness contribute to China's export volume, especially the latter factor. China's demand for imports is more income elastic than price elastic. The Marshall-Lerner condition holds in China, mainly due to high export price elasticity. The trend current account was reduced during the Asian financial crisis and China's WTO accession in 2001. This contrasts to all previous studies. Then it increased during 2002-2008 to levels much higher than previous studies indicate. Despite the drop in 2009, the trend current account still remains high.

Third, relative terms of trade, openness to international trade and government budget balance have a positive impact on sustainable current account, whilst the relative dependency ratio of the young has a negative impact. The sustainable current account has been increasing gradually since 1984 and peaked at 6.5% in 2006. Our estimates are generally higher than the levels assumed by previous papers, especially during 2004-2009.

Fourth, our misalignment rates suggest that the CNY/USD real exchange rate was overvalued for most of the years from the mid-1990s until 2003, especially during the Asian financial crisis (1997-1999) and China's early WTO accession years (2001-2002). This contrasts to all previous studies. The RMB was undervalued against the USD in real terms by an average of 30.8% during 2004-2008, though it dropped dramatically to 16.8% in 2009. To correct this misalignment, an average revaluation of 20.7% was required over the period 2004-2009. Nevertheless, this required revaluation is well below the average of 35% suggested by previous studies and we observe an even smaller required revaluation of 14.3% for 2009. In addition, we simulated misalignment rates for the period 2004-2009 using a sustainable current account of 3% of GDP. The findings show much higher required revaluation of 35.9% during 2004-2009, which suggests that exogenous inputs about the sustainable current account can lead to results biased towards higher undervaluation.

The value of the Chinese RMB is often the focus of debate in discussions about global current account re-balancing. It is often argued that in order to reduce China's current account surplus and the US current account deficit, revaluation of the RMB is essential. But the level to which China's current account should return to is usually based on assumptions about a target current account. Our study highlights the role of longer term economic fundamentals in correcting misalignments. For instance, other things being equal, nations with persistent high saving ratio and others with persistent low saving ratio may create equally persistent current account surplus and deficit respectively. Changing the values of currencies may help to partially alleviate the global current account imbalances, but structural changes such as saving and consumption habit are also very crucial. For instance, only when pension and medical care systems become more developed, can the saving ratio in China be reduced gradually. Currency adjustments should be regarded as part of a broad range of policy changes rather than the only one.

Appendix A. Real Export and Import Prices Equations

BDW (2006) model the trade prices as functions of world export price, domestic output price and commodity price.

$$(N \times XP) = \left((N \times WXP)^{\gamma} P^{1-\gamma}\right)^{\alpha} (N \times CXP)^{1-\alpha} \tag{A.1}$$

$$(N \times MP) = \left((N \times WXP)^{\phi} P^{1-\phi}\right)^{\beta} (N \times CMP)^{1-\beta} \tag{A.2}$$

where N , XP , MP , WXP , P , CXP and CMP are nominal exchange rate (domestic currency per USD), export price, import price, world export price, domestic output price, commodity export price and commodity import price respectively. All prices are converted into domestic currency.
Divided both sides of equations (A.1) and (A.2) by P :

$$\frac{N \times XP}{P} = \frac{(N \times WXP)^{\alpha\gamma+(1-\alpha)}}{P^{\alpha\gamma+(1-\alpha)}} \times \frac{(N \times CXP)^{1-\alpha}}{(N \times WXP)^{1-\alpha}} \tag{A.3}$$

$$\frac{N \times MP}{P} = \frac{(N \times WXP)^{\beta\phi+(1-\beta)}}{P^{\beta\phi+(1-\beta)}} \times \frac{(N \times CMP)^{1-\beta}}{(N \times WXP)^{1-\beta}} \tag{A.4}$$

Based on the definition of the real exchange rate ($E = N \times \frac{WXP}{P}$), equations (A.3) and (A.4) can be rewritten as:

$$RXP = RXP(E, RCXP) \tag{3}$$

$$RMP = RMP(E, RCMP) \tag{5}$$

where RXP , RMP , $RCXP$ and $RCMP$ are real export price (export price/domestic output price), real import price (import price/domestic output price), real commodity export price (commodity export price/world export price) and real commodity import price (commodity import price/world export price) respectively.

Appendix B. Data Sources and Variable Measurement

The main data sources include *International Financial Statistics* (*IFS*), *World Development Indicators* (*WDI*), *United Nations Conference on Trade and Development* (*UNCTAD*), and various issues of *China Statistical Yearbook* (*CSY*) of the National Bureau of Statistics of China. Sample frequency is quarterly and sample period is 1982q1-2009q4. All price indices have 2000 as the base year (2000=100).

1. Variables in trade equations

Nominal Exchange Rate (N) (CNY per USD): *IFS* (line 924.RF.ZF). It is also converted into an index and named the *N* index.
Real (Y) and Nominal GDP (NY): real GDP (in CNY) is obtained from Zhang (2011). Nominal GDP for China (in CNY) from 1992q1 to 2009q4 is collected from *CSY*. China's nominal GDP from 1982q1 to 1991q4 is obtained by using the average quarterly (year-on-year) nominal GDP growth rate during 1993q1 and 2009q4 and calculating backwards from 1991q4 to 1982q1.
GDP Price Deflator Index (P): GDP price deflator index for China (in CNY) is derived by dividing nominal GDP by real GDP and then multiplying by 100[31].
World Export Price Index (WXP): *IFS* (line 74.DZF) (in USD).
World Export Volume (WX): world export value (line 70.DZF, *IFS*) (in USD) is converted into in CNY using *N* and world export price (*WXP*) is also converted into in CNY using *N* index. World export value adjusted by world export price delivers world export volume in CNY.
Real Exchange Rate (E): $E=N\times(WXP/P)$ as in equation (1).
Export and Import Values for China: *IFS* (lines 70.DZF and 71.DZF) (in USD).
Export Price (XP) and Import Price (MP) indices for China: Quarterly trade prices for China are not available. Using a similar methodology as Zhang (2001), we use quarterly export price of developing Asian countries (including China) from IFS to estimate quarterly export price for China. Specifically, quarterly patterns of export price of developing Asian counties are applied to China but adjusted by multiply factors. The multiply factor for a particular year is the annual export price of China divided by that of developing Asia countries so that the average quarterly export price is identical to actual annual data. Same method is used to construct quarterly import prices for China. Quarterly and annual trade prices for developing Asia countries are collected from *IFS* (lines 74.DZF and 75.DZF). Annual trade prices for China are collected from *WDI*.
Export Volume (X) and Import Volume for China (M): China's export value and export price are converted into in CNY using N and N index respectively. By adjusting China's export value by the export prices index, we obtain export volume for China. Same applies to import volume for China.
Export Competitiveness index of China (XCOM): it is defined as the world export price index (in USD) divided by China's export price index (in USD) times 100.
Import Competitiveness index of China (MCOM): it is defined as China's import price index (in USD) divided by the domestic GDP price deflator index (converted from in CNY to in USD using N index) times 100.

[31] We calculate the annual GDP price deflator of period 1982-1993 as the average of quarterly data and they are very close (almost identical) to annual GDP price deflator data from the *WDI*.

Real Export (RXP) and Import (RMP) Price indices: they are defined as the export and import prices indices (in USD) divided by the domestic GDP price deflator index (in USD) times 100.
Commodity Export (CXP) and Import Prices (CMP): In BDW (2006), the commodity export price is defined as a weighted average of the commodity prices of the following categories: oil prices, world food prices, world beverage prices, world agricultural non food prices, and world metals and minerals prices, with the weights based on the relevant shares of world commodity exports and imports in total trade. We adopt the same strategy to calculate commodity prices for China. Quarterly prices for each category of commodity (in USD) are collected from *UNCTAD*. Annual weights of the above mentioned categories are available from *CSY* but quarterly weights are not available. Following Cheung *et al* (2009), quadratic interpolation is used to translate the annual data into quarterly. Thus annual weights are interpolated to quarterly frequency using quadratic matching average.
Real Commodity Export (RCXP) and Import Price (RCMP) indices: These are derived by dividing commodity export and import prices by the world export prices (in USD) and multiplying by 100.
Net IPD Flows and Net Transfer: *IFS* provides annual IPD credit and debt (lines 78AGDZF and 78AHDZF) and annual current transfer credit and debt (lines 78AJDZF and 78AKDZF) (in USD) for China since 1982. The sum of the first pair gives the net IPD flows and that of the second pair gives the net transfer. Quarterly data, however, are not available. Annual data are interpolated to quarterly frequency using quadratic matching sum. Data are then converted to CNY using N and adjusted by the GDP price deflator index to obtain the real values.

2. Variables in sustainable current account

We construct variables in sustainable current account following Chinn and Prasad (2003) and Chinn and Ito (2008). Note that whilst in these two studies relative variables are measured as relative to mean across all countries included in their analysis, ours are measured as relative to the world.
Current Account to GDP Ratio of China (CAY): current account of China (in USD) is available from 1982 but only at annual frequency from *IFS* (line 78ALDZF). As the main component of the current account of China is the net trade, we use the pattern of net trade to project that of the current account. Specifically, quarterly patterns of net trade (export value minus import value) adjusted by multiply factors is used as current account for China. The multiply factor for a particular year is the annual current account divided by that of the net trade so that the average quarterly current account is identical to actual annual data. Quarterly and annual export and import values are collected from IFS (lines 70.DZF and 71.DZF). The quarterly current account is then converted to CNY using N and divided by nominal GDP to obtain the current account to GDP ratio[32].
Net foreign assets to GDP ratio of China (NFAGDP): Quarterly data for net foreign assets for China (in CNY) are collected from *IFS* (line 31 NZF) and divided by nominal GDP to obtain the ratio. In addition, we also collected an alternative *NFAGDP* at annual frequency from updated and extended version of dataset constructed by Lane and Milesi-Ferretti (2007) for period 1982-2007. We extend the

[32] We will obtain the same ratio if we using real current account divided by real GDP as both variables will be adjusted using GDP price deflator index.

data for China to 2009 using the same methods and interpolate annual to quarterly data using quadratic matching average.
Government budget balance to GDP ratio of China (GOVBGDP): Annual data for China's government budget balance (in CNY) are available from *CSY* for period 1982-2009 but quarterly data are not available. Annual data are interpolated to quarterly frequency using quadratic matching sum and are then divided by nominal GDP to obtain the ratio.
Relative terms of trade index of China (RTOT): Annual data of terms of trade for the sample period are collected from *WDI* but quarterly data are not available. We use quarterly terms of trade of developing Asian countries (including China) from *IFS* to estimate that of China. The quarterly patterns of terms of trade of developing Asian counties are applied to China after adjusted by multiply factors. The multiply factor for a particular year is the annual terms of trade of China divided by that of developing Asia countries so that the average of quarterly terms of trade is identical to actual annual data. Quarterly and annual export and import prices for developing Asia countries are collected from IFS (lines 74.DZF and 75.DZF) to construct the terms of trade index (export price divided by import price). RTOT is measured as China relative to the world. Quarterly data of world export and import prices are collected from the *IFS* and then the terms of trade is calculated as export divided by import price.
Relative dependency ratio of the young (RELDEPY) and the old (RELDEPO): The former variable is measured as population under 15 divided by total population; the latter is measured as population above 65 divided by total population. Relative means value of China relative to the world. Annual data for China and the world are collected from *WDI* and interpolated to quarterly frequency using quadratic matching average.
Indicator of financial deepening of China (FDEEP): It is measured as the domestic credit to nominal GDP ratio of China. Quarterly data for domestic credit (in CNY) are collected from *IFS* (line32.ZF).
Indicator of Openness of China (OPEN): It is measured as the sum of exports and imports to nominal GDP ratio.
Relative PPP adjusted real GDP per capita (RELY): Annual PPP adjusted real GDP per capita data for China and the world are collected from *WDI*. Value of China minus that of the world delivers the relative variable. It is then interpolated to quarterly frequency using quadratic matching average
RELYSQ: square of the variable RELY.
Real GDP growth of China (YGR): Real GDP of China is used to obtain the grow rates.

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Table 1. ADF unit roots tests

Trade equations variables						
	General to specific method			Modified AIC		
	Lag	ADF stats		Lag	ADF stats	
Variables	length	Level	1st Difference	length	Level	1st Difference
X	4	-0.6193	-3.7160*	4	-0.6193	-3.7160*
WT	5	-0.6172	-5.0321*	6	-0.9120	-4.7171*
XCOM	2	-1.8038	-8.3199*	3	-1.6680	-5.8857*
M	4	-0.8060	-3.9906*	4	-0.8060	-3.9906*
Y	6	-0.4544	-3.6790*	6	-0.4544	-3.6790*
MCOM	4	-2.8547	-4.2477*	4	-2.8547	-4.2477*
RXP	4	-1.3381	-4.3435*	4	-1.3381	-4.3435*
RMP	4	-2.8548	-4.2483*	4	-2.8548	-4.2483*
E	4	-2.2011	-3.8619*	6	-2.4167	-4.3273*
RCXP	2	-0.8522	-6.3655*	2	-0.8522	-6.3655*
RCMP	2	-1.0158	-5.9952*	4	-2.8548	-4.2483*
Medium-term sustainable current account variables						
	General to specific method			Modified AIC		
	Lag	ADF stats		Lag	ADF stats	
Variables	length	Level	1st Difference	length	Level	1st Difference
CAY	3	-1.4097	-6.2183*	3	-1.4097	-6.2183*
NFAGDP	6	2.4062	-3.4085*	4	0.6350	-3.0122*
GOVBGDP	5	-2.6438	-4.2167*	6	-2.2683	-4.2433*
RTOT	3	-2.2998	-6.8433*	3	-2.2998	-6.8433*
RELDEPY	6	-0.2589	-3.3024*	6	-0.2589	-3.3024*
RELDEPO	5	-1.0004	-4.3528*	5	-1.0004	-4.3528*
FDEEP	4	-0.9459	-3.5562*	5	-0.8947	-3.6245*
OPEN	4	-1.8642	-3.0944*	6	-1.6856	-4.2275*
RELY	2	1.5652	1.4521	2	1.5652	1.4521
RELYSQ	3	0.4774	4.1788	2	-0.0234	5.1702
YGR	3	-3.6857*		0	-3.0531*	

Note: Please see Appendix B for variable description. We set a maximum lag length of 6 and lag length for the ADF test is chosen using both the general to specific method of Campbell and Perron (1991) and the Modified Akaike Criteria (AIC) proposed by Ng and Perron (2001). All trade variables are measured in natural logarithm. * indicates 5% significance level.

Table 2. Gregory and Hansen tests for cointegration with one structural break at unknown date—trade equations

	Model C		Model C/T		Model C/S	
	G-H test stats (Z_t)	Break date	G-H test stats (Z_t)	Break date	G-H test stats (Z_t)	Break date
Export Volume Equation	-7.9342***	2001q3	-9.7022***	1986q1	-8.3141***	1992q2
Import Volume Equation	-6.5933***	1994q3	-5.1525*	1994q3	-9.2889***	1996q2
Real Export Price Equation	-5.3334**	1993q3	-5.9525***	1990q1	-5.7785**	1993q3
Real Import Price Equation	-4.7085*	1999q2	-5.1755*	1988q2	-5.6907**	1987q1

Note: Eviews programme used to obtain the Gregory and Hansen (G-H) test statistics is available upon request. In particular, trim is set to be 0.15. The critical values for the Z_t test for Model C are -4.69, -4.92 and -5.44 for significance level of 10%, 5% and 1% respectively; for Model C/T are -5.03, -5.29 and -5.80 for significance level of 10%, 5% and 1% respectively; for Model C/S are -5.23, -5.50 and -5.97 for significance level of 10%, 5% and 1% respectively. Critical values are obtained from Gregory and Hansen (1996). *, ** and *** indicate significance level of 10%, 5% and 1% respectively.

Table 3. Cointegration estimates for trade equations

Export Volume Equation		Import Volume Equation		Real Export Price Equation[a]		Real Import Price Equation[abc]	
Model C/T		Model C/T		Model C/T		Model C/S	
WT	1.4478*** (0.1877)	Y	0.8274*** (0.1367)	RCXP	0.0563** (0.0238)	RCMP	-0.0296 (0.0623)
XCOM	1.6284*** (0.1540)	MCOM	-0.1415* (0.0790)	E	0.9344*** (0.0244)	E	1.0325*** (0.0659)
C	-15.6936*** (1.7833)	C	-1.9160** (0.9639)	T	0.0026*** (0.0004)	D87q2-09q4 ×RCMP	0.1555** (0.0648)
T	0.0134*** (0.0033)	T	0.0159*** (0.0034)	D90q2-09q4	0.1109*** (0.0301)	D87q2-09q4 ×E	-0.1766** (0.0683)
D86q2-09q4	-0.2178*** (0.0448)	D94q4-09q4	-0.1833*** (0.0521)				
Adjustment Factor in ECM	-0.5421*** (0.1808)	Adjustment Factor in ECM	-0.2890** (0.1312)	Adjustment Factor in ECM	-0.0878 (0.1034)	Adjustment Factor in ECM	-0.1639 (0.1873)

Note: Standard errors are in brackets. *, ** and *** indicate significance level of 10%, 5% and 1% respectively. D donates a dummy variable. For instance, D86q2-09q4 indicates a dummy that equals to unity during 1986q2-2009q4 and zero during other quarters of the sample period.
a. the constant is deleted from equation as it is insignificant.
b. D87q2-09q4 is also excluded as when it is included RCMP is insignificant in both periods.
c. We re-estimate real import price equation (model C/S) excluding RCMP as it is insignificant. The coefficients for E, D87q2-09q4×RCMP and D87q2-09q4×E are 1.0006*** (0.0077), 0.1259*** (0.0176) and -0.1447*** (0.0195) respectively.

Table 4. Gregory and Hansen tests for cointegration with one structural break at unknown date—sustainable current account

	Model C		Model C/T		Model C/S	
	G-H Test stats (Z_t)	Break date	G-H Test stats (Z_t)	Break date	G-H Test stats (Z_t)	Break date
Sustainable Current Account Equation	-5.7251**	1992q2	-6.8133***	1992q4	-7.1429**	1992q2

Note: The critical values for Z_t test for Model C are -5.31, -5.56 and -6.05 for significance level of 10%, 5% and 1% respectively; for Model C/T are -5.59, -5.83 and -6.36 for significance level of 10%, 5% and 1% respectively; for Model C/S are -6.17, -6.41 and -6.92 for significance level of 10%, 5% and 1% respectively. Critical values are obtained from Gregory and Hansen (1996). *, ** and *** indicate significance level of 10%, 5% and 1% respectively.

Table 5. Cointegration estimates for sustainable current account

Model C									
RTOT	0.1411*** (0.0325)	RELDEPY	-0.1213*** (0.0241)	OPEN	0.1645** (0.0208)	GOVBGDP	1.1240*** (0.0380)	D92q3-09q4	-1.6239* (0.8444)
Adjustment Factor in ECM			-0.3296*** (0.0913)						

Note: Standard errors are in brackets. *, ** and *** indicate significance level of 10%, 5% and 1% respectively. The constant is deleted from equation as it is insignificant.

Table 6. Decomposition of coefficients in trade price equations (1982-2009)

Export prices (XP)			Import prices (MP)		
World (WXP) γ	Domestic (P) $(1-\gamma)$	Commodity (CXP) $(1-\alpha)$	World (WXP) β	Domestic (P) $(1-\beta)$	Commodity (CMP) $(1-\theta)$
0.93	0.07	0.06	0.83	0.17	0.13

Note: coefficients are obtained using equations (A.3) and (A.4) in Appendix A.

Table 7. Current accounts and revaluation required (%) in the real CNY/USD exchange rate: annualised data 2004-2009

Our Findings						
Year	2004	2005	2006	2007	2008	2009
CAY	2.9	7.1	9.1	10.7	9.3	6.1
TCAY	7.9	10.5	11.1	12.2	12.4	6.5
SCAY	5.7	6.3	6.5	6.1	5.2	4.1
Actual real CNY/USD rates	8.6	8.5	8.2	7.8	7.3	6.4
FEER rates	7.6	7.0	6.5	5.7	4.9	5.5
Misalignment Rates (%)	-15.1	-25.9	-27.6	-38.1	-47.4	-16.8
Revaluation Required (%)	-11.6	-17.8	-21.4	-27.2	-31.7	-14.3
Simulations using 3% SCAY						
Year	2004	2005	2006	2007	2008	2009
FEER rates	6.1	5.3	4.9	4.4	4.1	5.0
Misalignment Rates (%)	-43.1	-64.9	-68.9	-79.0	-78.1	-26.7
Revaluation Required (%)	-29.2	-37.4	-40.6	-43.8	-43.4	-20.9

Note: CAY, TCAY and SCAY denote actual current account, trend current account and sustainable current account as a percentage of GDP respectively. Misalignment rate is calculated as -(E-FEER)/FEER*100%. Negative misalignment rates indicate undervaluation. Revaluation required is calculated as -(E-FEER)/E*100%. Average of quarterly data is used as annualised data.

Figure 1. Actual current account (CAY), trend (TCAY) and sustainable current account (SCAY) (% of GDP)

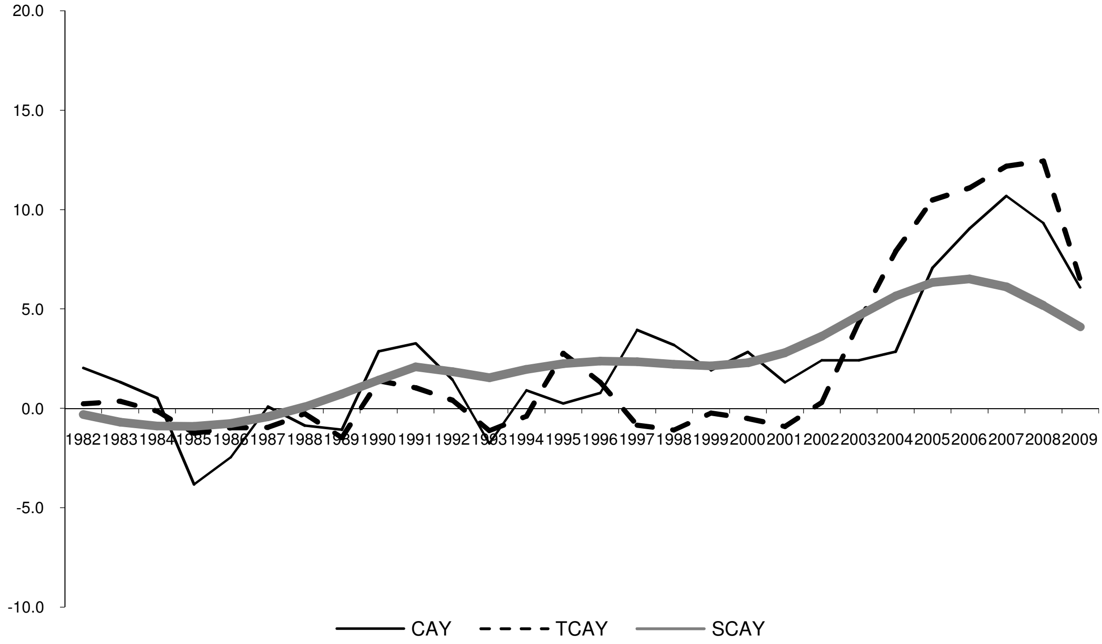


Figure 2. Actual CNY/USD real exchange rate and FEER

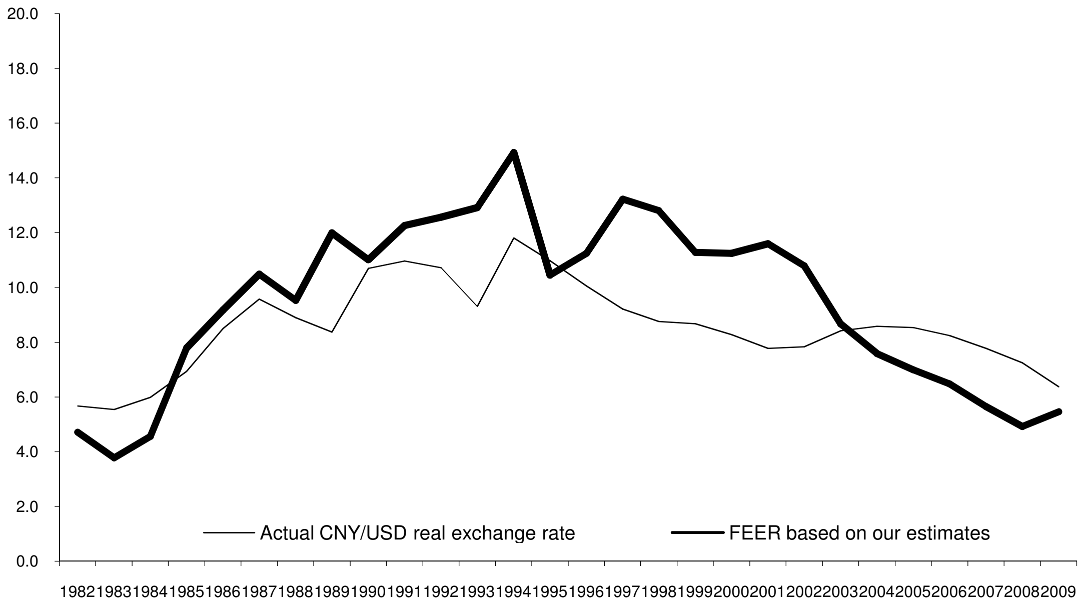
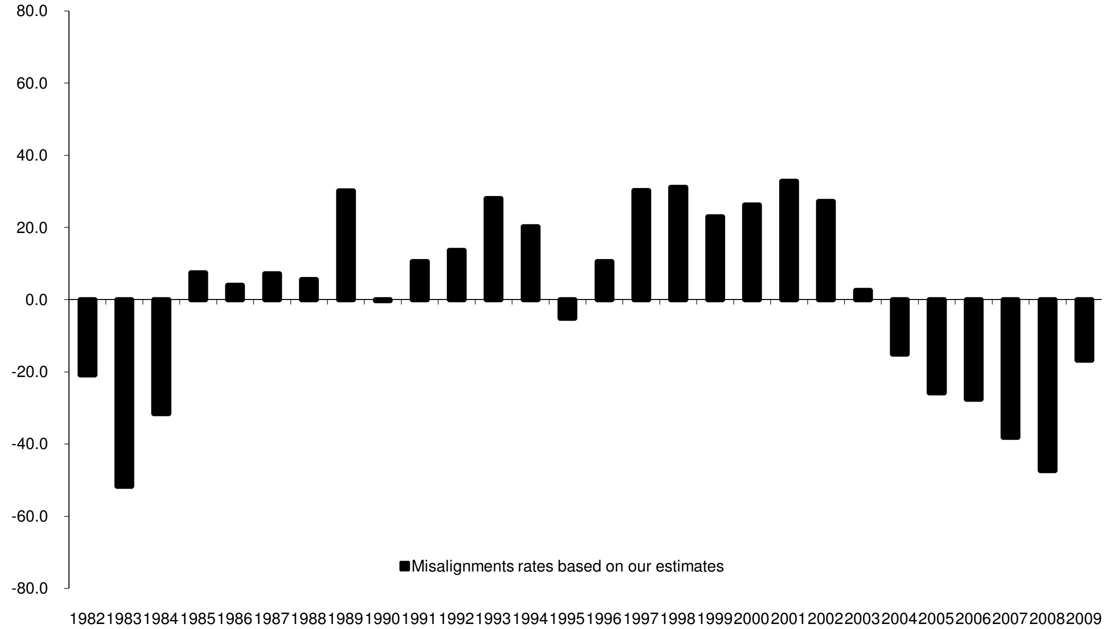


Figure 3. Misalignment rates (%)



Note: Misalignment rate=-(E-FEER)/FEER*100%; a positive (negative) misalignment rate implies an overvaluation (undervaluation) of the RMB. E denotes the actual CNY/USD real exchange rate (equation (1)).