HONG KONG INSTITUTE FOR MONETARY RESEARCH

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HKIMR Working Paper No.24/2010

September 2010

Hong Kong Institute for Monetary Research
(a company incorporated with limited liability)

Measuring Renminbi Misalignment: Where Do We Stand?

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September 2010

Abstract

The value of China's currency, the renminbi (RMB), and the conduct of China's exchange rate policy have generated intense debate in academic and international policy circles. Despite the accumulation of empirical evidence regarding the degree of RMB misalignment over the past few years, the debate continues unabated. In this study, we highlight the challenges to properly assessing the nature and degree of currency misalignment, in terms of the choice of the model, the method of calculation, and data uncertainty. In particular, we demonstrate the susceptibility of misalignment estimates to model selection and data revisions. Further, we explicitly discuss the implications of sampling uncertainty for determining the extent of RMB misalignment.

Keywords: Absolute Purchasing Power Parity, China, Currency Misalignment, Sampling Uncertainty, Data Revision

JEL Classification: F31, F41

Acknowledgments: We thank the participants of the 2010 International Economics and Finance Society (Beijing) conference, the IX Korea and the World Economy conference, and the Fifth International Annual Conference on Industrial Economics and Economic Theory for their helpful comments. Financial support of faculty research funds of the University of California at Santa Cruz and the Grant-in-aid for Scientific Research of the Japan Society for the Promotion of Science is gratefully acknowledged.

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1. Introduction

While the European sovereign debt crisis, sometimes referred to as the Aegean Contagion, has briefly distracted the international community from the debate over potential misalignment of the Chinese currency renminbi (RMB), it has not weakened critics' calls for RMB appreciation. Since its return in mid-2008 to a stable exchange rate policy in the midst of the global financial crisis, China has been subject to severe pressure to revalue its currency. The typical criticism is that China manipulates its currency value to keep it at an artificially low level to give Chinese exports an unfair competitive edge in the global market. To some observers, China's currency manipulation policy is both the cause of the global imbalances that led to the 2008-09 global financial crisis *and* a hindrance to the global economy's recovery.

The Obama administration, for example, has recently stepped up its criticism of China's exchange rate policy as China resumed *de facto* pegging against the dollar even as US unemployment soared. Pressure for action is more marked (as it usually is) in the Congress, where legislation has been submitted that would impose across-the-board tariffs on imports from China. In response to these protectionist sentiments, as well as pressure from other governments, the People's Bank of China (2010) issued a statement on "Further Reform the RMB Exchange Rate Regime and Enhance the RMB Exchange Rate Flexibility" on June 19, 2010. The statement marks a return to the 'managed floating system' adopted in 2005.[1] As expected by most commentators, the resulting RMB appreciation was measured and gradual. Thus, while the policy change has been welcomed, it has not silenced the critics, who argue for even more rapid RMB appreciation.

As noted by Cheung, Chinn and Fujii (2010), few phrases in open economy macroeconomics have excited as much attention in recent times and yet elicit so little understanding as 'currency misalignment.' Clearly, the determination of the extent of RMB misalignment is of great interest to policy makers and financial institutions. For economists, a currency is undervalued when it can be exchanged for a lesser amount of foreign currency than economic fundamentals indicate it should. In this case, the allegation is that it takes more units (yuan) of the Chinese currency RMB to buy a single dollar than is deemed appropriate. The overarching issue is, of course, how to define the appropriate or, in economic jargon, the equilibrium value of RMB.

First, which exchange rate model is appropriate for evaluating RMB's fair value? The current state of exchange rate economics, apparently, offers little guidance – there is little consensus on what constitutes the right exchange rate model in each circumstance, and different models might be relevant over different

[1] On July 21, 2005, China revalued the RMB against the US dollar by 2.1 percent to RMB 8.11 to one US dollar and announced the implementation of a new 'managed floating system' wherein the exchange rate was to be determined with reference to a basket of currencies. The policy, which resembles an upward crawl against the dollar ended in July 2008.

time horizons.[2] In the absence of a commonly accepted theoretical model, assertions about currency misalignment should be interpreted with great care. Second, theoretical considerations aside, the assessment of RMB valuation confronts the same empirical issues that are inherent in most empirical economic exercises. Some canonical empirical issues include the proper specification of regression equations, the informativeness of the data, and – particularly important in the case of China – the impact of data quality.

Empirical studies on RMB valuation adopt different exchange rate models, implement diverse statistical methodologies, and incorporate data encompassing different time periods. A misalignment finding will depend, to varying degrees, on choices made over these three dimensions. Not surprisingly, various studies yield a wide range of misalignment estimates – anywhere from RMB being undervalued by 15% to 50%, to being overvalued. In view of these different misalignment estimates, one might wish to consult a number of estimates before coming to any conclusions regarding the proper course of action.

In the remainder of the paper, we highlight the difficulties involved in determining the equilibrium value of the RMB – in terms of model selection, the calculation of the degree of misalignment, and data uncertainty. In the next section, we briefly discuss some general issues of exchange rate modeling and selectively review some empirical evidence. Section 3 presents the relative-price-income relationship which is also known as the Penn effect. The Penn effect specification is used to illustrate the implications of sampling uncertainty and data revisions for the debate on RMB valuation. Section 4 presents some concluding remarks.

2. Exchange Rate Modeling and RMB Valuation

2.1 What is the Equilibrium Exchange Rate?

The difficulties inherent in empirical exchange rate modeling are well documented in the seminal study Meese and Rogoff (1983). Since its publication, the inability of extant exchange rate models – both theoretically and empirically based – to explain exchange rates has been reported in a voluminous collection of studies. Cheung, Chinn and Garcia Pascual (2005), for example, present some recent evidence on this issue. A direct implication of this strand of literature is that the prospect of having a commonly agreed framework to assess RMB valuation is pretty unpromising, at least, at the theoretical level.

[2] Even this is not an obvious proposition. For instance, in the Dornbusch overshooting model, the exchange rate can deviate from its long-run value in the short run, and yet the exchange rate is in this context takes on a value entirely consistent with short-run market fundamentals. Hence, the time frame is and the exchange rate trajectory is important as well. The short-run and long-run dichotomy is important in a number of models. See, for example, Hinkle and Montiel (1999).

Even though journalistic accounts typically refer to nominal exchange rates, real exchange rates are the subject of academic currency misalignment analysis. While the Meese and Rogoff results pertain to nominal exchange rates, the same conclusions typically apply to real exchange rates – an unsurprising outcome given the close correspondence of nominal and real exchange rates, except in cases of countries experiencing rapid inflation.

A related issue is that standard or conventional equilibrium exchange rate models may not work for a transition or emerging economy. China has undergone rapid structural changes, transitioning from central planning to greater market orientation over the last couple of decades. Even now China can be characterized as a hybrid economy, with strong elements of both 'planned' and 'market' systems. Though it is an integral part of a financially globalized world, China still retains a wide array of capital controls. These special attributes heighten concerns regarding the appropriate model for determining RMB's equilibrium value.

As summarized in Cheung, Chinn and Fujii (2010), most of the extant studies on RMB misalignment adopt some theoretical framework that can be placed in the categories of relative purchasing power parity, the Penn effect, the productivity approach, the behavioral equilibrium exchange rate model, the fundamental equilibrium exchange rate approach, and the macroeconomic balance effect approach. We will briefly comment on results from these frameworks later.

Given an estimate of the degree of misalignment, what do we know about the probability that the currency under consideration is misaligned? This is a statistical question that arises from the fact that statistical techniques are employed to assess the degree of misalignment. The typical approach is to consider the misalignment estimate and its sampling uncertainty given by, say, the confidence interval. As noted by Cheung, Chinn and Fujii (2007), the data used to assess RMB misalignment may not be very informative in the sense that the sampling uncertainty of a misalignment estimate could make it difficult to infer whether the RMB is undervalued or not.

Data uncertainty is another factor that may affect the estimation of the degree of currency misalignment. Indeed, the quality and accuracy of Chinese economic data is a subject of concern for most empirical studies. Those concerns are exacerbated by the occasionally large changes in the accounting methodologies used in generating some of the major macroeconomic indicators. For instance, in December 2005, China revised its gross domestic product data based on a new nationwide economic survey. As a result, the 2004 GDP was revised upward by 17%. These data revisions are sufficiently massive that results based upon pre-revision data could be overturned.

In addition to data uncertainty associated with statistics sourced from the Chinese statistical agencies, international and multilateral organizations also revise data in a manner that could affect the calculations of the equilibrium RMB exchange rate. Take for instance the empirical studies on RMB valuation based

on price and output data derived from the International Comparison Program exercise. In 2007, the World Bank, together with the Asian Development Bank, released the 2005 International Comparison Program benchmark and revised the corresponding data. The new release came with a substantial revision of some national data. For example, China's PPP-per capita gross domestic product data were revised down by 40% as the price level was revised upward. In the subsequent sections, we will discuss the implications of the change in the International Comparison Program benchmark for the debate of RMB valuation.

Other practical issues compound the challenges faced by researchers. For instance, after selecting a theoretical framework to work with, researchers have to derive an empirical specification and choose an estimation technique, preferably based on theory. It is not uncommon that empirical studies based on the same theoretical framework employ different estimation specifications and econometric techniques. It is more than commonplace to observe that estimates of currency misalignment vary substantially with estimation specification and econometric techniques. Dunaway, Leigh and Li (2009), for instance, show that a small change in model specification could give rise to very different equilibrium estimates.

We merely mention the potential issues raised by specification uncertainty and different choices of estimation techniques, as these issues are beyond the scope of the current paper.

2.2 Some Estimates of the Degree of RMB Misalignment

2.1.1 The Deviation from the Trend Estimates

There is no shortage of estimates of the degree of RMB misalignment. Here, we first present two recent RMB misalignment estimates based on the relative purchasing power parity and the deviation from the trend approach, which is quite commonly adopted in the aftermath of the 1997 Asian financial crisis. To be sure, we do not take these estimates as definitive. We mean to use them to illustrate parts of the complexity surrounding the debate on RMB valuation.

Figure 1 depicts the bilateral real exchange rate between the US and the RMB from January 1987 to September 2009. The real rate is obtained by deflating the official exchange rate by the US and Chinese consumer price indexes. A higher value means a stronger Chinese currency. The solid black line gives the real exchange rate based on the official exchange rate. The dashed line gives the "adjusted" real exchange rate, which incorporates the swap rates used in the pre-1994 mega-devaluation period.[3]

[3] Fernald, Edison and Loungani (1999) argue that the 1994 RMB devaluation is better interpreted as a unification of the official and swap rates.

In line with expectations, the RMB experienced a steady decline in value between the 1997 financial crisis and its 2005 policy change and a steady appreciation after the policy change. The main difference between the official and adjusted rates is their trending behaviors. Over the entire sample period, the RMB based on the official rate shows a downward trend while the one based on the adjusted rate displays an upward trend.

In the early warning system literature that developed in the wake of the 1997 Asian financial crisis, a typical measure of currency misalignment was the deviation from a deterministic trend. The linear trends fitted to the official and "adjusted" exchange rates are indicated, respectively, by the broken line and dotted line in Figure 1. Although the official and adjusted rates have trends of different signs, the trend deviation measure of misalignment indicates that both rates represent an RMB overvaluation – the "adjusted" displays an *over*valuation of 10.4% and the official rate an *over*valuation of 16.8% – in September of 2009.

A natural reaction would be to argue that simple bilateral comparisons are faulty. We would agree. Compared with bilateral rates, trade weighted effective exchange rate indexes, for example, should provide more accurate information about overall competitiveness. However, appealing to trade weighted exchange rates would not necessarily fully resolve matters. Figure 2 depicts the IMF's trade weighted effective exchange rate index for the period 1980 to 2009. The sample mean and linear trend estimated over the available sample are also plotted. In this case, the deviation from the trend indicates a 36% *over*valuation and the deviation from the mean gives a 7.5% *under*valuation at the beginning of 2010.

The import of these two figures is not their implied misalignment estimates but the fragility and sensitivity of these estimates. For instance, the use of different series and different measures of "trend" could lead to very different misalignment estimates. It is obvious that, if we start the sample period from 1994, the trend deviation measure will yield some substantial *under*valuation estimates. Further, different misalignment estimates could be generated by using different price deflators and by using a broken trend or a nonlinear trend instead of a linear trend. For some more elaborate frameworks for assessing currency valuation, the analogues of these sources of ambiguities are the specification uncertainty, the sample period selection, and the choice of data series. Thus, a proper assessment of currency misalignment has to be placed in the context of both theory and empirics.

Another point worth mentioning is the interpretation of misalignment estimates based on data constructed from price indexes. In judging the difficulty of interpreting the degree of misalignment, it is essential that the estimate is able to inform us on how the Chinese current exchange rate stands relative to others, and not only relative to its own past. Real exchange rate data derived from relative price indexes tell us the relative purchasing power of two currencies relative to the base years of price indexes and no information on the actual relative purchasing power. The trend lines plotted in Figures 1 and 2 should be appropriately interpreted as trend lines relative to the actual equilibrium value. Thus, it is hard to gauge the degree of

misalignment of the current real rate. Consequently, the models based upon relative PPP are not suitable for assessment RMB misalignment, nor are the empirical exchange rate models that rely upon price indexes.

2.2.2 Some Alternative Estimates

Table 1 presents some recent estimates of the degree of RMB misalignment. As summarized in Cheung, Chinn and Fujii (2010), most of these estimates of the degree of RMB misalignment were obtained from the typical theoretical frameworks including the relative purchasing power parity, the Penn effect, the productivity approach, the behavioral equilibrium exchange rate model, the fundamental equilibrium exchange rate approach, and the macroeconomic balance effect approach. One striking observation is the dispersion of these misalignment estimates; they range from a 49% undervaluation to a 36% overvaluation. Even if we drop the apparently *ad hoc* deviation from the trend estimates, the remaining estimates still spread over a rather wide range.

The limitations of the relative purchasing power parity method are discussed in the previous subsection. The Penn effect approach will be used to illustrate the sampling uncertainty and data uncertainty in the next section. In the current subsection, we follow Cheung, Chinn and Fujii (2010) and offer some brief comments on the other methods.

The productivity approach focuses on the link between real exchange rates and productivity differentials between traded and nontraded sectors across countries. This approach is motivated by the Balassa-Samuelon hypothesis. Given the practical difficulties of calculating sectoral productivities, the empirical regression equation typically includes proxies for sectoral productivities and macroeconomic variables that are believed to affect them.

In addition to productivity differentials, the behavioral equilibrium exchange rate model includes some economic variables to capture the medium-term fundamentals of the exchange rate. The list of these variables varies across studies adopting the behavioral equilibrium exchange rate framework. The typical variables included in an empirical behavioral equilibrium exchange rate equation are interest differentials, government spending, terms of trade, net foreign assets, and trade openness. Some versions of the behavioral equilibrium exchange rate model are also known as the equilibrium real exchange rate model.

The macroeconomic balance effect approach and the fundamental equilibrium exchange rate approach share some similar motivations. Both approaches recognize that, in the medium term, the current account balance could be non-zero. The determination of the equilibrium exchange rate involves a two-step procedure. First, the “normal” current account balance is identified. The norm could be determined on a judgmental basis that depends on researchers’ priors. This strategy is typically adopted by the fundamental equilibrium exchange rate approach. The macroeconomic balance effect approach tends to

use the saving and investment behaviors and the budget balance dynamics to infer the norm of e current account. Typically, budget balance dynamics are assumed to be exogenous. In the second stage, trade elasticities are used to back out the "equilibrium" exchange rate that would generate the normal current account balance.

Given the discussion in the previous subsections, it is not surprising to note that, for these different approaches, the choices of the empirical specification, the proxies for productivity differentials and variables that capture the medium-term fundamentals, the normal current account balance, and the trade elasticity could have discernable effects on the estimated equilibrium exchange rate. The variability of the estimates in Table 1 could just reflect the sensitivity of these estimation techniques. Of course, the choice of sample period also plays a role in this respect.

Some of these studies, in fact, note the sensitivity of their estimates to the sample period, model specification, and parameter assumptions (Hu and Chen, 2010; Wang and Hu, 2010). Also, Dunaway, Leigh and Li (2009) demonstrate that the equilibrium RMB real exchange rate estimates obtained by approaches and models that are commonly used in the literature exhibit substantial variations in response to small perturbations in model specifications, explanatory variable definitions, and sample periods. In other words, inferences regarding currency misalignment could be very sensitive to small changes in the way the equilibrium exchange rate is estimated.

3. The Penn Effect

The Penn effect refers to the robust empirical positive association between national price levels and real per capita incomes across countries documented by a series of Penn studies (Kravis and Lipsey, 1983, 1987; Kravis, Heston and Summers, 1978; Summers and Heston, 1991; Samuelson, 1994). Theoretical explanations of the Penn effect are offered by, for example, Balassa (1964), Samuelson (1964), Bhagwati (1984), Bergstrand (1991), and Bergin, Glick and Taylor (2006).

In the recent debate on RMB valuation, the Penn effect framework has been adopted to assess the degree of RMB misalignment (Frankel, 2006; Cheung, Chinn and Fujii, 2007; Coudert and Couharde, 2007). The basic Penn effect regression equation is given by

$$r_{i,t} = \beta_0 + \beta_1 y_{i,t} + u_{i,t} \quad (1)$$

where $r_{i,t}$ and $y_{i,t}$ are, respectively, country *i*'s price level and *per capita* income relative to the US in real terms. The estimation of the relative-price-income relationship requires comparable data on prices and income between countries. To ensure data compatibility, the price levels and national gross domestic

products measured in PPP terms offered by the International Comparison Program could be used. The results discussed in this section are based on International Comparison Program data obtained from the World Bank's *World Development Indicators*. This data set covers a large cross section of countries and a long sample period.

The inference of currency misalignment based on (1) hinges upon the robust positive Penn effect. It is implicitly assumed that some real exchange rates relative to the US may be overvalued, some may be undervalued, but they are at the equilibrium level on average.

It is important to acknowledge the limitations of the relative-price-income relationship. Theoretically, the equilibrium exchange rate in the Balassa-Samuelson model is the one that is consistent with both internal and external balances. In the short- to medium-term, however, internal or external balance is not guaranteed. Thus, the estimated exchange rate measure is properly interpreted as a long-run measure and is ill-suited (on its own) to analyzing short-run phenomena. One potential remedy is to include control variables that are relevant for (short-run) variations in internal and external balances. This remedy is explicitly discussed later.[4]

One point worth mentioning is that studies adopting the relative-price-income relationship approach yield the largest estimated degree of RMB undervaluation (Cairns, 2005). Those implementing either the relative PPP or flow equilibrium approaches typically find smaller estimates of the extent of the RMB undervaluation. Thus, adopting the Penn effect framework does not bias the results against RMB undervaluation.

3.1 Misalignment Estimates and Sampling Uncertainty

Cheung, Chinn and Fujii (2007) presented results of estimating (1). The data were drawn from the *World Development Indicators* database between 2005 and 2006. It comprises a maximum of 160 countries from 1975-2004. Their regression results, summarized in Table A-1 in the appendix, confirm the presence of a significant positive Penn effect in the data.[5] One of the key emphases of Cheung, Chinn and Fujii (2007) is the role of sampling uncertainty in interpreting the estimated degree of misalignment. That is, in addition to estimating the economic magnitude of the implied misalignments, they emphasize the importance of taking the level of precision in assessing misalignment estimates. To this end, they presented both the estimated degree of misalignment and its sampling uncertainty given by its prediction error bands.

[4] Frankel (2006) discusses whether one can speak of an "equilibrium exchange rate" when there is more than one sector to consider. Engel (2009) argues that "external balance" needs to be defined in terms of efficiency in global resource allocation, rather than trade balances in the usual sense.

[5] For brevity, the regression results discussed in this and subsequent subsections are summarized in the appendix. Additional information about these and related regression results are available from the authors.

Figure 3, reproduced from Cheung, Chinn and Fujii (2007), gives the scatter plot of the data, the predicted real exchange rates, the standard error bands, and the path of the actual RMB real exchange rate derived from the 1975-2004 PPP-based income data. The time paths of the actual and predicted RMB values are traced out also in Figure 4. It is interesting to follow the path that the RMB has traced out in these graphs. It begins the sample as overvalued, and over the next three decades it moves toward the predicted equilibrium value and then overshoots, so that, by 2004, it is substantially undervalued – by 53% in level terms (greater in log terms). Importantly, however, in 2004 the RMB was more than one standard error – but less than two standard errors – away from the predicted value, which in the present context is interpreted as the "equilibrium" value.

In other words, by the standard statistical criterion that applied economists commonly appeal to, the RMB is not undervalued (as of 2004) in a statistically significant sense. The wide dispersion of observations in the scatter plots should give pause to those who would make strong statements regarding the exact degree of misalignment.

To construct the prediction error confidence interval drawn in the figures, Cheung, Chinn and Fujii (2007) followed the standard econometric procedure. The width of the interval is determined by two components, namely the variance of the regression error term (u_{it} in (1)) and the variance of the coefficient estimators ($\hat{\beta}_0$ and $\hat{\beta}_1$). It is quite well known that, under standard assumptions, the coefficient estimators, $\hat{\beta}_0$ and $\hat{\beta}_1$, are consistent and their variance decreases as the sample size increases – in technical jargon, their variance goes to zero asymptotically and does not contribute to the width of the prediction error confidence interval. However, the variance of the regression error term does not go to zero as the sample size increases.

Intuitively, the increase in observations helps reduce the uncertainty associated with the estimates of β_0 and β_1 but not the uncertainty of the regression equation itself as represented by the variance of u_{it}. Unless we have a perfectly fitted regression, the variance of u_{it} will be non-zero. That is, for a given regression, we cannot predict perfectly; what we could do is to reduce the coefficient sampling uncertainty.

What happens when we compute the prediction error confidence interval using only information on the variance of the coefficient estimators? In such a case, the resulting interval gives only the range in which the regression line can lie, under a pre-specified confidence level and ignores the fact that the underlying regression is not an exact relationship between real exchange rates and real income levels. The interval over-states the ability to predict real exchange rates and, hence, the evidence of a significant misalignment. Thus, an appropriate procedure to construct the RMB prediction error confidence interval is

crucial to making the misalignment assessment, especially given the large data dispersion observed in Figure 3.[6]

That said, how should the results in Figure 3 be interpreted? While the real exchange rate-income relationship is a robust empirical regularity (that is, the positive slope coefficient estimate is highly statistically significant), the data are not sufficiently informative to allow us to make sharp inferences about the extent to which the Chinese RMB is misaligned. We emphasize that, even though the result does not allow us to conclude there is undervaluation, neither does it rule out RMB undervaluation. This is a point worth repeating since it is not always explicitly stated despite its importance. The problem we are facing is that the data and models in hand fail to statistically distinguish between a *wide* range of competing hypotheses regarding the extent of the RMB misalignment.[7]

In passing, it is noted that the implication of sampling uncertainty for undervaluation assessment survives several robustness checks. Specifically, Cheung, Chinn and Fujii (2007) showed that the evidence of RMB undervaluation is weakened once serial correlation in (1) is accounted for. Further subsample analyses and inclusion of control variables do not qualitatively alter the basic results.

3.2 Misalignment Estimates and Data Revision, I

As noted earlier in this section, the relevance of using (1) to infer currency misalignment depends on the price and output data across country. The key data used to generate results presented in the previous subsection were based on the 1993 International Comparison Program benchmark. Some emerging economies including China and India did not fully participant in the 1993 International Comparison Program. Thus, the data for these countries are "projected" and, hence, subject to some unknown errors.

In 2008, the World Bank in cooperation with the Asian Development Bank reported new estimates of output and price level data measured in PPP terms, which are based on new benchmark data on prices generated by the 2005 International Comparison Project. These new estimates effectively revise down, for example, the 2005 China's PPP-based *per capita* GDP (or revise up its PPP-based real exchange rate) by about 40% below (above) the previously reported figures.[8] Taking proper account of this revision requires re-estimating the regressions because data for many countries were substantially revised as well. The implications of this data revision for assessing RMB misalignment are discussed in Cheung, Chinn and Fujii (2009).

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[6] There is a deep question of whether one should use the same level of significance for policy question as for academic research. For instance, Frankel (2010) has suggested that a 50% significance level may be more appropriate for deciding upon whether a currency is misaligned.

[7] See Eichengreen (2007) for a discussion of the issue.

[8] In the case of India, the PPP-based *per capita* GDP was revised down by 36%. See Asian Development Bank (2007). Also, see Elekdag and Lall (2008) and International Comparison Program (2007) for a discussions about the data update program.

To formally assess the implications of data revision, we obtained the data from the *World Development Indicators* database to re-estimate (1). Data for a maximum of 164 countries and the sample period 1980-2007 were downloaded in November 2008.[9] Figure 5 is the regression scatter plot with the revised data. As also shown by the estimation results reported in Table A-2 in the appendix, the estimated Penn effects are qualitatively comparable to those in Cheung, Chinn and Fujii (2007). However, the *magnitude* of the change in the implied misalignment for the RMB is striking.

Similar to Figure 3, Figure 5 plots the actual and predicted rates to trace out the RMB time path. As of 2007, the estimated degree of RMB undervaluation is about 10% in level terms, which represents a massive reduction in the extent of misalignment. The new undervaluation estimate for 2004 turns out to be around 18%, only about one-third in magnitude of the old estimate of 53%. The maximal undervaluation is identified in 1993.

Figure 6 shows the time series path of the actual RMB rate, against its predicted value and corresponding two standard prediction error bands. It is clear from the graph that there is no statistically significant RMB misalignment. In fact, while being below the estimated equilibrium line, the RMB has never gone below the one standard error prediction band over the past two decades. In sum, the results based on the revised data suggest that the extent of the RMB undervaluation is modest and, in the statistical sense, indistinguishable from zero.

These figures suggest that our previous finding of substantial misalignment – on the order of 50% – is not robust to the data revision implemented by the World Bank.

Again, the implication of sampling uncertainty for undervaluation assessment survives robustness checks mentioned in the previous subsection. Indeed, the use of the Prais-Winsten procedure to correct serial correlation yields RMB overvaluation estimates.

3.3 Misalignment Estimates and Data Revision, II

The PPP-based price and output data for years other than the International Comparison Program benchmark years are constructed using the benchmark information and national data. As long as benchmark data and national data are revised, the PPP-based data could vary across different versions of *World Development Indicators*. In March 2010, we retrieved the necessary data to re-estimate (1). This time, data on 176 countries from 1980-2008 are available. The regression results are reported in Table A-

[9] The empirical results of Cheung, Chinn and Fujii (2009) are based on the WDI data extracted in March 2008, which contains the observations only up to 2006. Consequently, they do not match with the results presented in this subsection due to difference in the samples and to any possible revision that might have occurred at the source between March and November in 2008.

3 in the appendix. Again, the updated data display a significantly positive Penn effect. The resulting RMB misalignment estimates, nonetheless, are different from previous cases.

Figure 7 plots the actual and predicted rates and traces out the RMB time path. It is found that the 2008 RMB *over*valuation of 5% is obtained from the most recent vintage of the *WDI*. While Chinese per capita income has risen about 15% by the end of 2009, and the equilibrium rate should have risen by about 2.8%, the trade weighted real exchange rate is about the same now as it was in 2008; thus according to our calculations, the Chinese RMB remains slightly overvalued.[10]

The time series path of the actual RMB rate, against its predicted value and corresponding two standard prediction error bands presented in Figure 8 basically give the same story. The newer data set provides weaker evidence of RMB undervaluation than does the old dataset.

In the last few subsections, we have observed that the evidence of RMB misalignment varies across different vintages of *WDI*. While we cannot reject the no-misalignment null, we also cannot reject, say, a null hypothesis of a 10% or even a 20% undervaluation at conventional significance levels. The essence of the discussion is the imprecision of our estimates and their sensitivity to data revision.

3.4 Discussion

The accuracy and quality of the new price and output data derived from the 2005 International Comparison Program benchmark are questioned by some researchers. For instance, there are concerns that data revisions for some developing countries including China may have induced biases going in the opposite direction to what existed before.

Deaton and Heston (2009), for example, suggest that the 2005 benchmark has over-stated the Chinese price level by 10% to 20%. If this is the case, then the implied equilibrium real RMB exchange rate and the point estimate of RMB undervaluation should be larger than those presented in the previous two subsections. In addition to the 2005 benchmark data, there are concerns about the quality of the projected data beyond the benchmark years. Thus, it is argued that only benchmark year data should be used to evaluate currency misalignment (Subramanian, 2010).

Understandably, the construction of national price data that are compatible and consistent across a large group of highly heterogeneous countries is a challenging task. Deaton and Heston (2009) offer a detailed discussion of theoretical and practical issues involved in the process of collecting the basic information and compiling the disaggregate and aggregate price level indexes. It is fair to say that these issues

[10] According to IMF *World Economic Outlook* database, year on year growth in per capita GDP is about 10% in both 2009 and 2010. Using this growth rate, and the 0.2 coefficient estimate yields the implied 2.8% appreciation.

associated with the construction of price and output data in PPP terms will complicate our discussion of using (1) to assess RMB misalignment. In fact, the complexity of the data issue reinforces the need to place a proper assessment of currency misalignment in the context of both theory and empirics.

4. Concluding Remarks

The lack of a commonly agreed upon equilibrium exchange rate model makes it a formidable task to determine the "appropriate" level of the exchange rate. Determining the equilibrium value of the RMB is no exception. In general, however, consumers of these analyses are typically unaware of these difficulties, and are wont to put too much emphasis on one given estimate or another.

In this study, we reiterate some of the theoretical and empirical issues that are relevant for the debate on RMB valuation. The simple relative purchasing power parity setting and the relative price-income relationship that is based on the robust empirical Penn effect are used to illustrate the arguments. Specifically, the results from various relative price-income regressions vividly demonstrate the roles of sampling uncertainty and data revision in evaluating the evidence of estimated RMB misalignment.

With the pre-2005 International Comparison program benchmark data, the estimated degree of RMB undervaluation is quantitatively large at the 50% plus level. Nonetheless, there is a high level of (sampling) uncertainty surrounding the point estimate of undervaluation and it is hard to assert that the empirical estimate is statistically significant. Further, the evidence of RMB undervaluation is noticeably weakened after accounting for serial correlation.

The post-2005 International Comparison Program benchmark data, which are believed to give a more accuracy description of prices around the world, offer a different view on the degree of RMB valuation. In essence, the estimated magnitude of RMB undervaluation is substantially reduced with the new data. This, combined with sampling uncertainty, makes it more difficult to infer a significant RMB misalignment.

It is only fair to note that there are concerns about the relevancy of sampling uncertainty and data revision for interpreting and assessing RMB valuation. However, the imprecision presented here is not unique to the approach we adopted, even though it is often conveniently ignored. Indeed, drastically different estimates of RMB misalignment, even from the same theoretical framework, could be easily found in the literature. Arguably, the phenomenon reflects the difficulty of modeling the equilibrium RMB exchange rate. The large variability of RMB misalignment estimates allows researchers and politicians alike to draw on "sound" arguments that suit their own prior beliefs.

Anecdotal evidence indicates that most researchers consider the RMB substantially undervalued and an immediate (and sharp) appreciation is warranted.[11] It is argued that, for instance, an RMB appreciation helps to improve, if not completely eradicate, global imbalances.

In the case of China, there is some reason to believe that trade flows might be less responsive to exchange rate changes than typically, given the high degree of production fragmentation.[12] Since China is a key component of the global production chain, the effect of an RMB appreciation on global imbalances could be ambiguous; an appreciation raises the relative price of exports, but lowers the price of inputs. The appreciation thus only affects the value added component of Chinese exports. Other effects are also possible; Devereux and Genberg (2007), for example, use an analytical model to illustrate that an RMB depreciation will have an immediate perverse effect and little short-run effect on the current account balance.

What happened when the Chinese RMB appreciated by about 20% between 2005 and 2008? During the appreciation period, China's imports increased as predicted by the usual economic theory. The striking fact is that China's exports to the US increased at a much faster rate (Figure 9). Overall, the Chinese current account surplus increased. Now, of course many other factors were changing at the same time; nonetheless, the fact that the China-US trade surplus increased suggests that we need to think deeply about how much exchange rate changes can accomplish in reducing global imbalances.

Both theory and practical experiences do not lend support to the view that a high RMB value could alone eliminate global imbalances. Changes in (short-term) exchange rates could have limited impact on the current account. From a macro perspective, current account balances are the result of net saving behaviors across countries. A single-minded focus on exchange rates may yield an unexpected side effect of diverting attention away from the roles of an appropriate mix of monetary and fiscal policies in solving the imbalance problem.

We have to re-emphasize that our findings should not be interpreted as significant evidence of *no* RMB undervaluation. Nor is our intention to argue for an inflexible RMB exchange rate. Rather, the evidence is indicative of the limitations of the models and the data in hands. Without a strong theoretical model and statistically significant evidence, assertions about currency misalignment should be interpreted with great caution.

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[11] There are, at least, a few prominent researchers who think that China should maintain a stable exchange rate regime and not appreciate the RMB (McKinnon, 2010; Mundell, 2004). Schwartz (2005) represented yet another view on the issue: China, and not outside sovereignties including the IMF and the US, should determine the complex issue of reforming its foreign exchange policy. Engel (2009) considers the case of a stable exchange regime. Dooley, Folkerts-Landau and Garber (2009) offer an alternative interpretation of China's role in global imbalances.

[12] For real exchange rate movements and intermediate product trade, see Parsley and Helen (2010). See Dean, Fung and Wang (2007) and Koopmans, Wang and Wei (2008) for relatively high Chinese value added shares in Chinese exports.

The difficulty of drawing a clear verdict on RMB misalignment does not necessarily mean that there should be no policy action. In the absence of a clear verdict, however, a gradual and prudent approach, instead of sharp-swing policy, of enhancing RBM exchange rate flexibility could avoid unintended adverse effects to China, to its trading partners, and to the global economy.

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Table 1. Some Recent Estimates of the Degree of RMB Misalignment

Estimate	As of	Source
- 49%	March 16, 2010	The Economist (2010), Big Mac Index
-33%;	March 2009	Cline and Willamson (2010), FEER
-31%*	2005	Subramanian (2010), Penn Effect
-21%**	end of 2008	Goldstein and Lardy (2009), External Balance
-17.5 **	2009	Wang and Hu (2010), FEER, external balance
-10%	2010Q1	Tenengauzer (2010), external balance
- 2.56%	2009Q4	Stupnytska *et al.* (2009), BEER
+5%	2008	CCF (2010)
+13.4%	2008Q4	Hu and Chen (2010), FEER
+16.8%	September 2009	CCF(2010), relative PPP, real US exchange rate
+36%	December 2009	CCF(2010), real PPP, trade-weighted exchange rate

* the average of estimates from adjusted data.
** the average of estimates

Figure 1. Real Chinese Exchange Rate, in Logs (Official and "Adjusted") and Trends

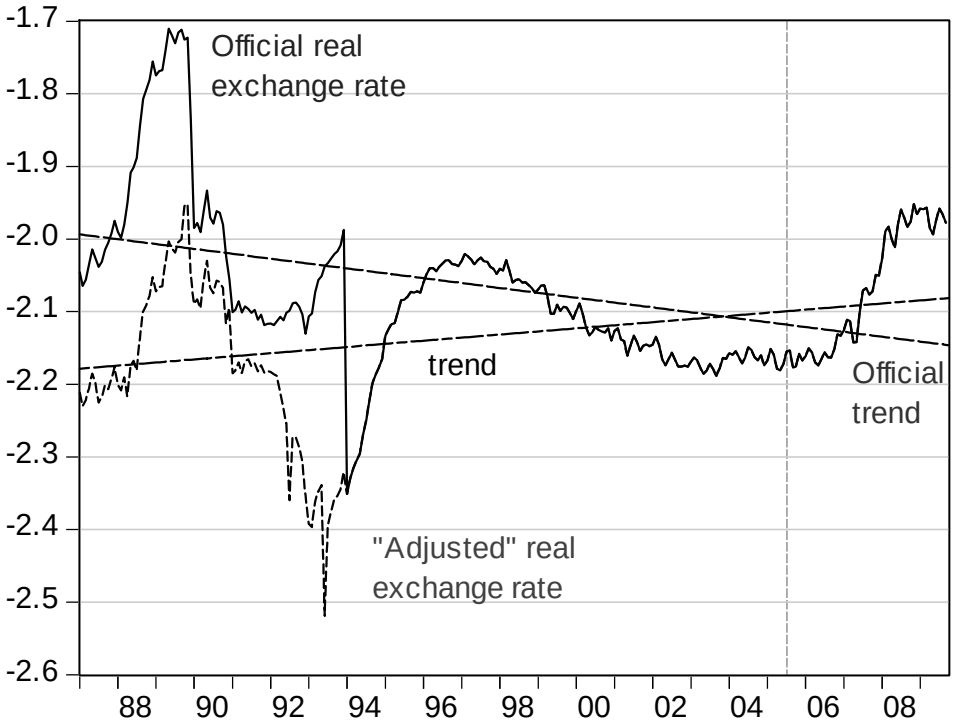


Figure 2. Misalignment via Linear Trends, Real Exchange Rate (Trade Weighted)

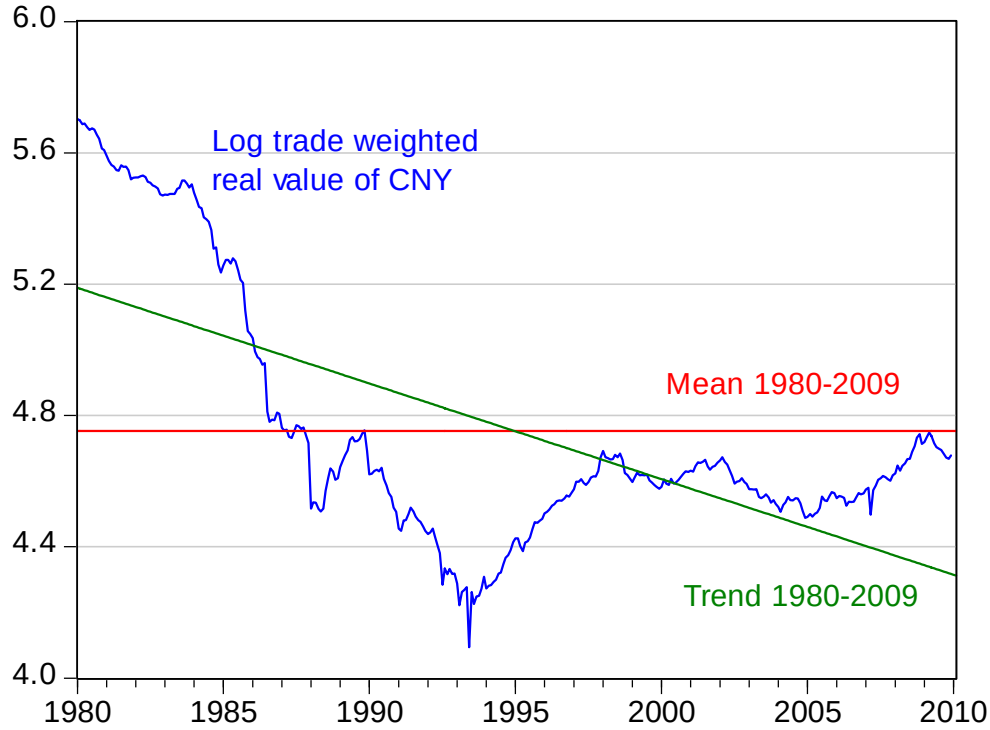


Figure 3. The Relative Price-income Relationship According to 2006 Vintage Data

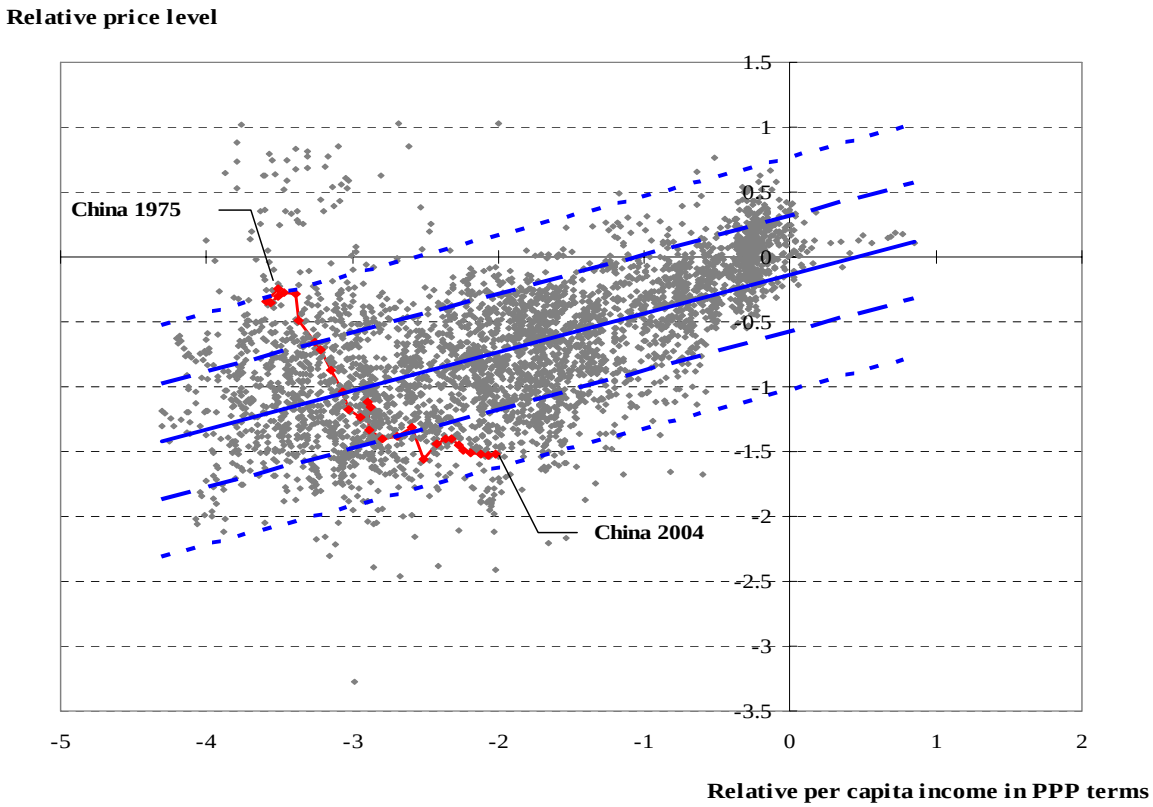


Figure 4. Actual and Predicted RMB Values Based on 2006 Vintage Data

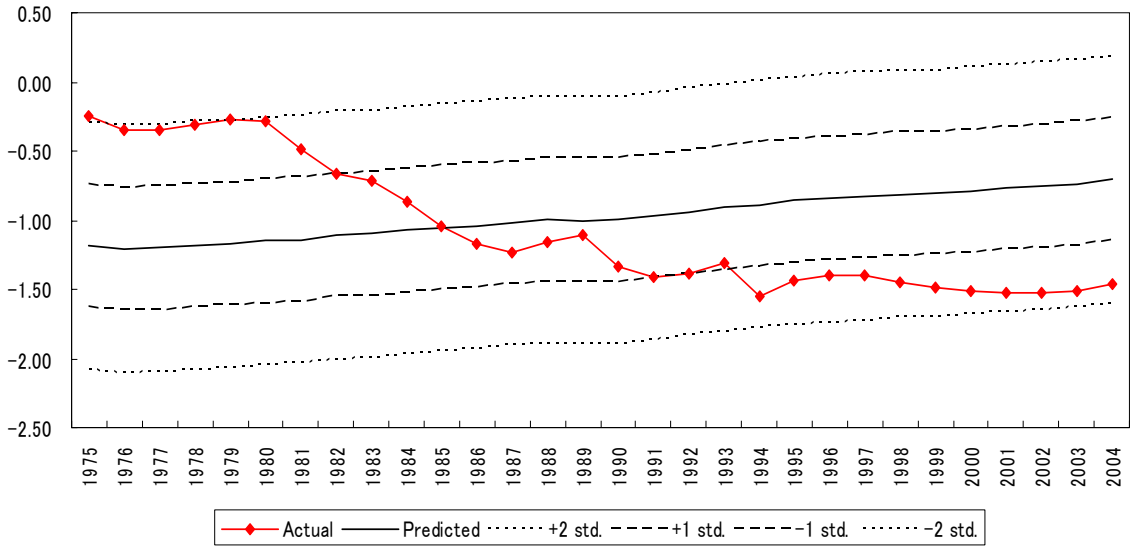


Figure 5. The Relative Price-income Relationship According to 2008 Vintage Data

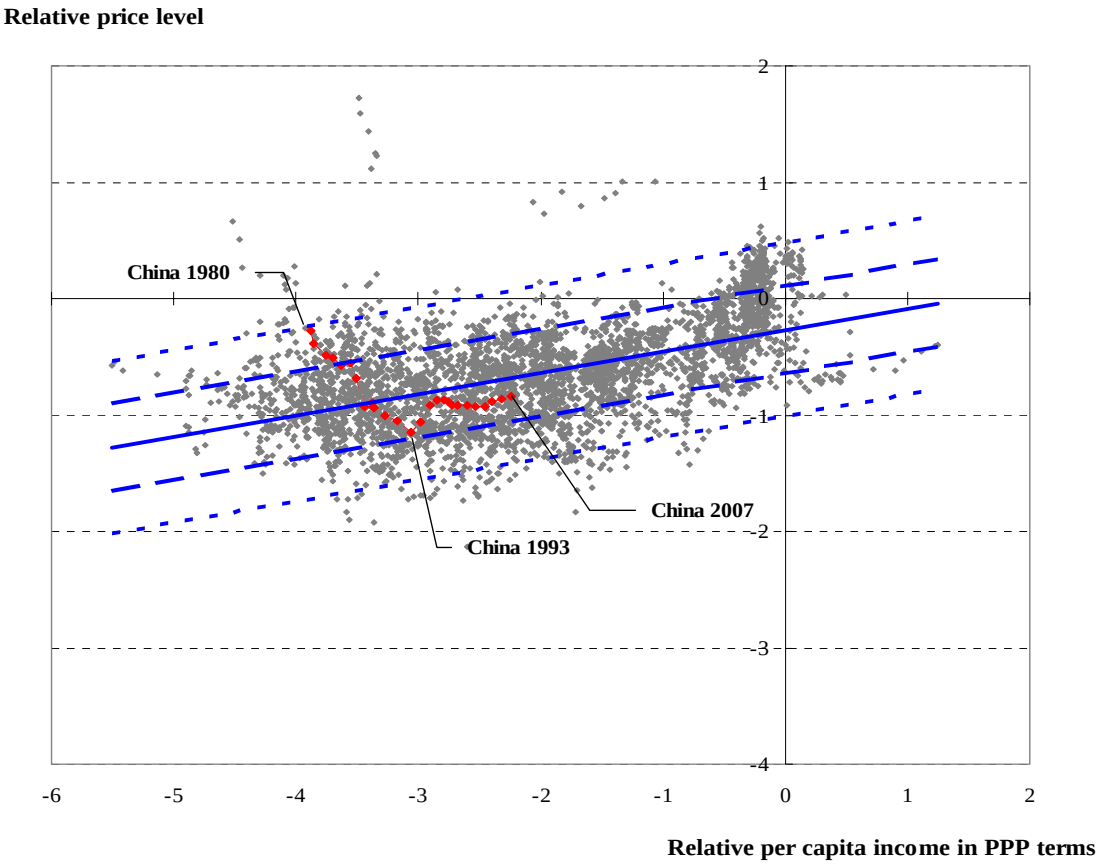


Figure 6. Actual and Predicted RMB Values Based on 2008 Vintage Data

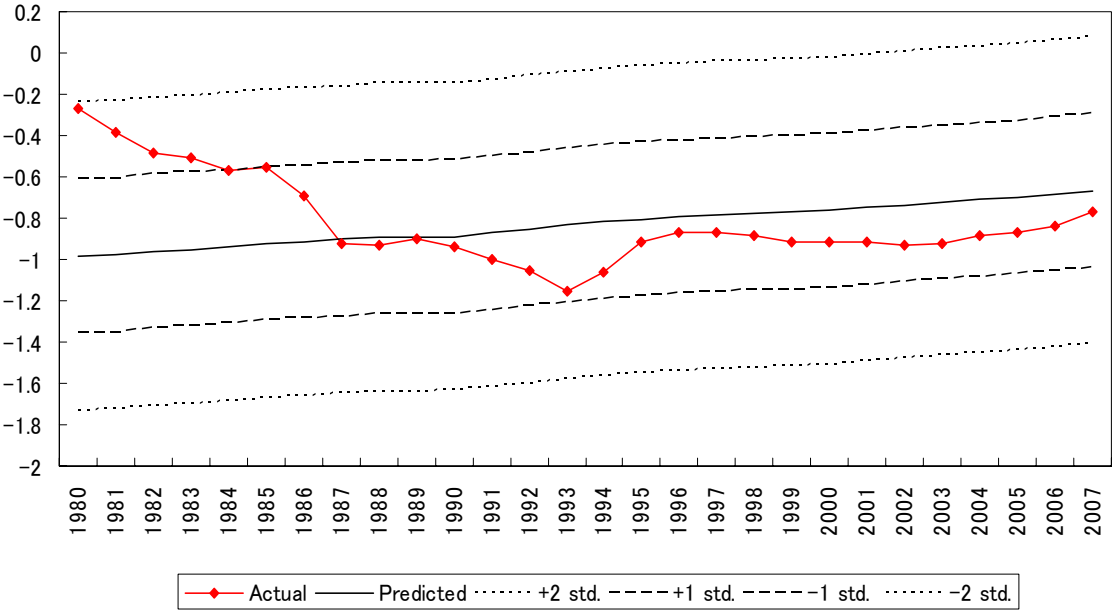


Figure 7. The Relative Price-income Relationship According to 2010 Vintage Data

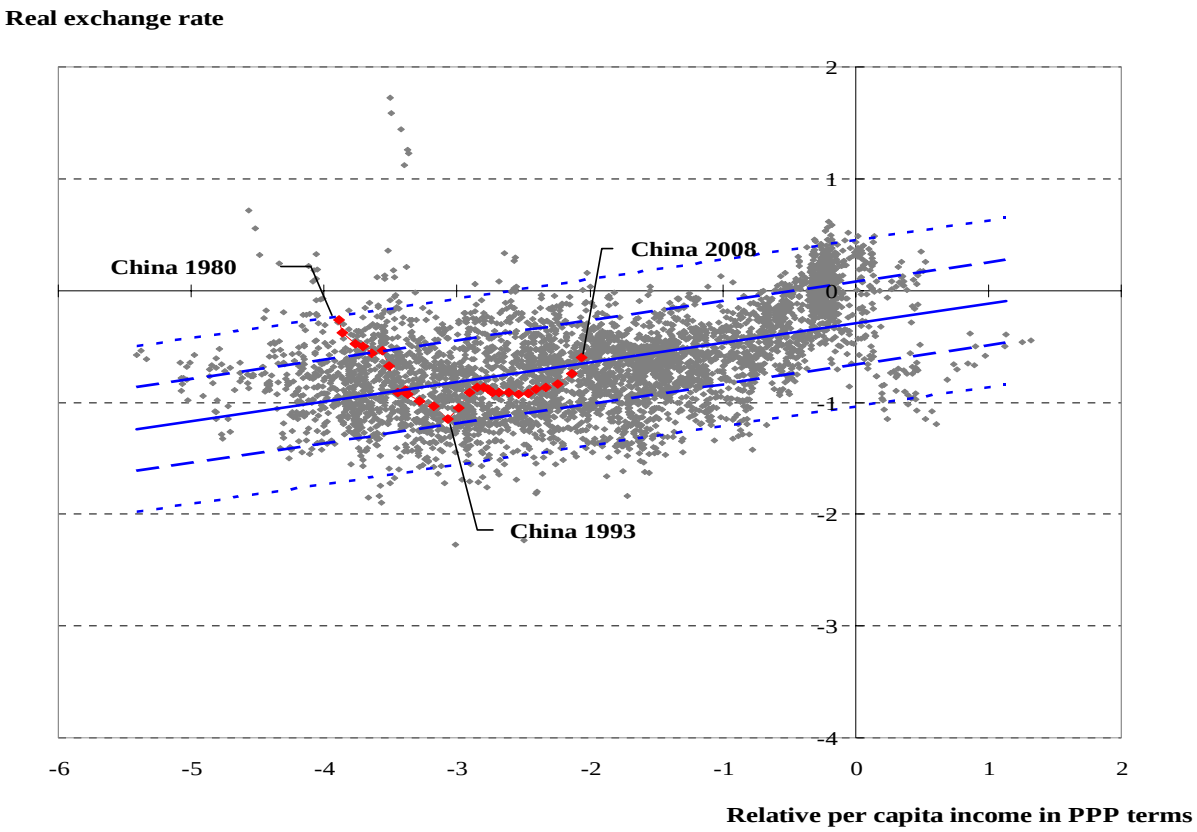


Figure 8. Actual and Predicted RMB Values Based on 2010 Vintage Data

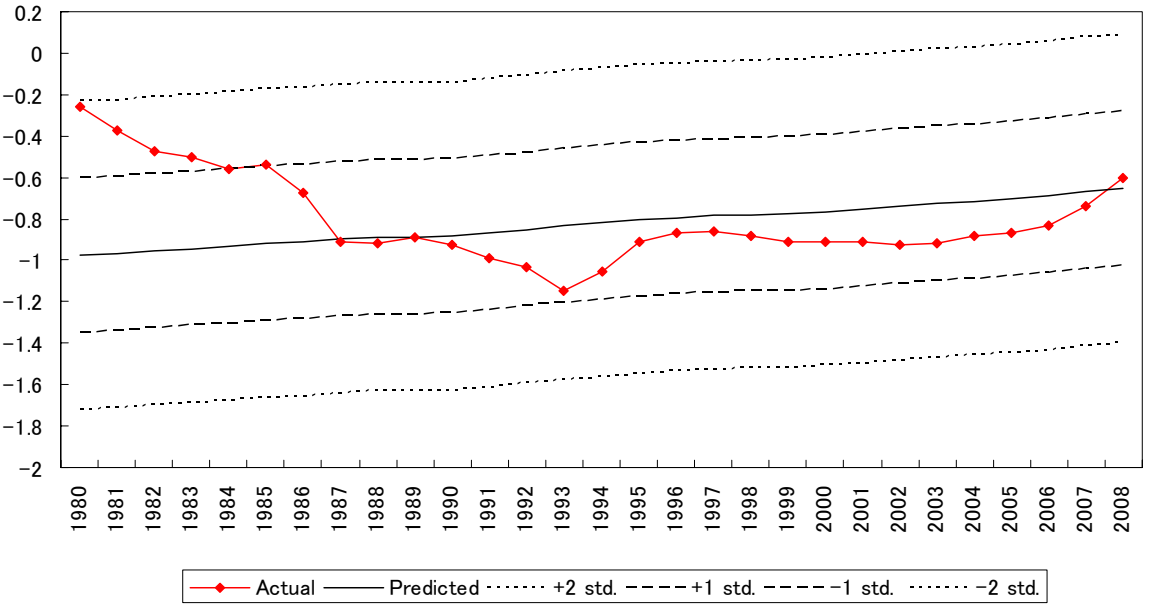
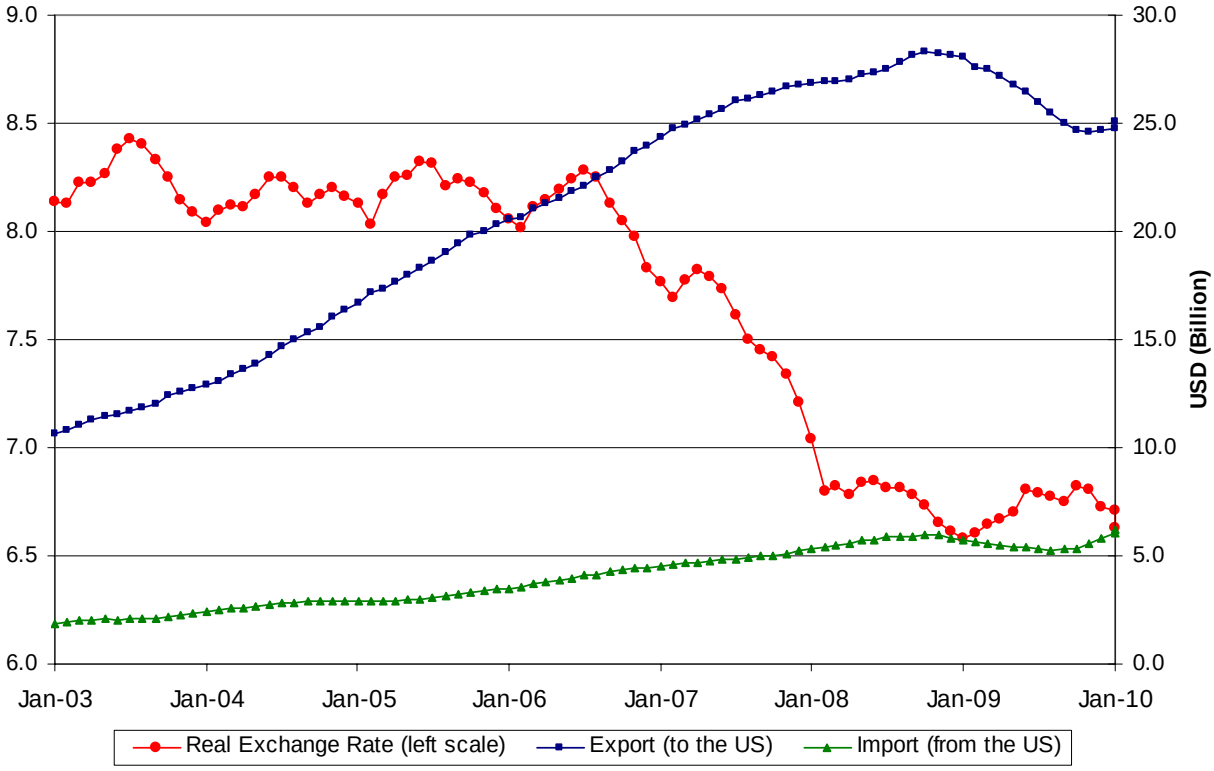


Figure 9. China-US Bilateral Trade and Real Exchange Rate



Note: Export and Import Data are 12-Month Moving Average.
Source: U.S. Department of Commerce and OECD Stats.

Appendix

Table A-1. The Relative Price-income Regression Results: 2006 Vintage Data

	USD-based GDP				PPP-based GDP				PPP-based GDP (Prais-Winsten)			
	Pooled OLS	Between	Fixed effects (Within)	Random effects	Pooled OLS	Between	Fixed effects (Within)	Random Effects	Pooled OLS	Between	Fixed effects (Within)	Random effects
GDP per capita	0.249** (0.003)	0.254** (0.015)	0.391** (0.029)	0.297** (0.012)	0.299** (0.006)	0.300** (0.028)	0.273** (0.031)	0.284** (0.017)	0.147** (0.021)	0.396** (0.028)	0.036 (0.025)	0.132** (0.021)
Constant	-.016** (0.008)	-.036 (0.050)	-	0.084 (0.042)	-.134** (0.011)	-.177** (0.061)	-	-.204** (0.043)	-.026** (0.002)	0.001 (0.004)	-	-.027** (0.003)
Adjusted R^2	0.496	0.617	0.763	0.496	0.349	0.413	0.754	0.349	0.012	0.389	0.021	0.012
F-test Statistic			29.468**				42.647**				1.218*	
Hausman test statistic				11.873**				0.167				39.384**
#obs	4018				4018				3958			

Notes: The table is reproduced from Cheung, Chinn and Fujii (2007). The entries summarize the results of estimating the relative price-income regression (1) in the main text, using the 2005-06 vintage of the World Development Indicator data. The sample covers a maximum of 160 countries for 1975-2004. The panel is unbalanced due to some missing observations. ** and * indicate 1% and 5% levels of significance, respectively. Heteroskedasticity-robust standard errors are given in parentheses underneath coefficient estimates. For the fixed effects models, the F-test statistics are reported for the null hypothesis of the equality of the constants across all countries in the sample. For the random effects models, the Hausman test statistics test for the independence between the time-invariant country-specific effects and the regressor. These results are based on a) US dollar-based GDP data, b) PPP-based GDP data, and c) PPP-based GDP data with the serial correlation adjustment Prais-Winsten procedure.

Table A-2. The Relative Price-income Regression Results: 2008 Vintage Data

	USD-based GDP				PPP-based GDP				PPP-based GDP (Prais-Winsten)			
	Pooled OLS	Between	Fixed effects	Random effects	Pooled OLS	Between	Fixed effects	Random effects	Pooled OLS	Between	Fixed effects	Random effects
GDP per	.173**	.173**	.283**	.209**	.183**	.175**	.283**	.229**	.154**	.238**	.103**	.137**
capita	(.013)	(.013)	(.064)	(.010)	(.019)	(.018)	(.064)	(.012)	(.016)	(.017)	(.021)	(.014)
Constant	-.157**	-.172**	-	-.069**	-.271**	-.307**	-	-.196**	-.022**	-.010**		-.024**
	(.040)	(.042)		(.035)	(.047)	(.044)		(.034)	(.003)	(.002)		(.003)
Adjusted R^2	.379	.517	.688	.379	.270	.344	.687	.270	.030	.536	.020	.030
F-test stat			26.57**				35.18**				.725	
Hausman stat				1.32**				.71				4.37*
#obs	4157				4169				4111			

Notes: The table summarizes the results of estimating the relative price-income regression (1) in the main text, using the November 2008 vintage of the World Development Indicator data. The sample covers a maximum of 164 countries for 1980-2007. The panel is unbalanced due to some missing observations. ** and * indicate 1% and 5% levels of significance, respectively. Heteroskedasticity-robust standard errors are given in parentheses underneath coefficient estimates. For the fixed effects models, the F-test statistics are reported for the null hypothesis of the equality of the constants across all countries in the sample. For the random effects models, the Hausman test statistics test for the independence between the time-invariant country-specific effects and the regressor. These results are based on a) US dollar-based GDP data, b) PPP-based GDP data, and c) PPP-based GDP data with the serial correlation adjustment Prais-Winsten procedure.

Table A-3. The Relative Price-income Regression Results: 2010 Vintage Data

	USD-based GDP				PPP-based GDP				PPP-based GDP (Prais-Winsten)			
	Pooled OLS	Between	Fixed effects	Random effects	Pooled OLS	Between	Fixed effects	Random effects	Pooled OLS	Between	Fixed effects	Random effects
GDP per	.166*	.164**	.322**	.217**	.174**	.165**	.323**	.245**	.160**	.229**	.119**	.146**
capita	(.003)	(.012)	(.021)	(.010)	(.004)	(.017)	(.021)	(.012)	(.016)	(.028)	(.022)	(.014)
Constant	-.179**	-.205**	-	-.055**	-.295**	-.334**	-	-.173**	-.018**	-.005**		-.019**
	(.010)	(.039)		(.033)	(.010)	(.041)		(.032)	(.002)	(.004)		(.003)
Adjusted R^2	.364	.502	.680	.364	.258	.329	.680	.258	.031	.266	.024	.0310
F-test stat			26.97**				35.62**				.822	
Hausman stat				30.43**				19.53**				2.299
#obs	4551				4584				4499			

Notes: The table summarizes the results of estimating the relative price-income regression (1) in the main text, using the 2010 vintage of the World Development Indicator data. The sample covers the maximum of 176 countries for 1980-2008. The panel is unbalanced due to some missing observations. ** and * indicate 1% and 5% levels of significance, respectively. Heteroskedasticity-robust standard errors are given in parentheses underneath coefficient estimates. For the fixed effects models, the F-test statistics are reported for the null hypothesis of the equality of the constants across all countries in the sample. For the random effects models, the Hausman test statistics test for the independence between the time-invariant country-specific effects and the regressor. These results are based on a) US dollar-based GDP data, b) PPP-based GDP data, and c) PPP-based GDP data with the serial correlation adjustment Prais-Winsten procedure.