The Overvaluation of Renminbi Undervaluation

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Abstract

We evaluate whether the Renminbi (RMB) is misaligned, relying upon conventional statistical methods of inference. A framework built around the relationship between relative price and relative output levels is used. We find that, once sampling uncertainty and serial correlation are accounted for, there is little strong evidence that the RMB is undervalued. The result is robust to various choices of country samples and sample periods, as well as to the inclusion of control variables.

Key words: absolute purchasing power parity, exchange rates, real income, capital controls, currency misalignment.

JEL classification: F31, F41

1. Introduction

China's currency, the Renminbi (RMB), has occupied a central role in the ongoing debate over the source of global current account imbalances. In this paper, we step back from the debates over the merits of one exchange rate regime versus another and whether a currency realignment is desirable (although our conclusions will necessarily inform the debate over what the appropriate actions might be). Rather, we focus the discussion of currency misalignment in terms of economic theory and empirics; in particular, we focus on the difficulty in measuring the "equilibrium real exchange rate" and on quantifying the uncertainty surrounding the measurement of the level of the equilibrium. In so doing, we sharpen our definition of what constitutes currency misalignment, at the cost of restricting the generality of our conclusions.

Specifically, we exploit a well-known relationship between deviations from absolute purchasing power parity and real per capita income using panel regression methods. The economic interpretation of this approach is that we are identifying the equilibrium exchange rate with a value of the currency that is consistent with internal equilibrium, conditional upon the time horizon being sufficiently long such that the external accounts are in balance. In addition to calculating the numerical magnitude of the currency misalignment implied by this approach, we also place the estimates in the context of statistical uncertainty. In this respect, we extend the standard practice of considering both economic and statistical significance in coefficient estimates to the prediction aspect.

We also extend the analysis by allowing for heterogeneity across country groupings and time periods. After conducting numerous checks, we conclude that the

RMB is undervalued in almost all samples. But, remarkably, in almost no case is the deviation statistically significant, and indeed, when serial correlation is accounted for, the extent of misalignment is not even statistically significant at the 50% level.

We further extend the analysis to allow for more conditioning variables. These additional factors include demographic variables, measures of trade openness, and policy factors such as the extent of capital controls. We also examine the possibility that institutional factors are statistically important. We conclude that they are, but that the inclusion of such factors does not change the basic message that the RMB appears to be substantially undervalued, although not by a statistically significant margin.

2. Preliminary Discussion

2.1 A Brief literature Review

At the heart of the debate over the right way of determining the appropriate exchange rate level are contrasting ideas of what constitutes an equilibrium exchange rate, what time frame the equilibrium condition pertains to, and, not least, what econometric method to implement.[1] Some short cuts have been used so often that some forget that they are short cuts.

Cheung et al. (forthcoming) reviews the literature. Most of these papers fall into familiar categories, either relying upon some form of relative purchasing power parity (PPP) or cost competitiveness calculation, the modeling of deviations from absolute PPP, a composite model incorporating several channels of effects (sometimes called behavioral equilibrium exchange rate models), or flow equilibrium models. Chart 1 provides a

[1] One relevant work is Hinkle and Montiel (1999).

typology of these approaches, further disaggregated by the data dimension (cross section, time series or both).[2]

The relative PPP comparisons are the easiest to make, in terms of numerical calculation. On the other hand, relative PPP is uninformative about how a country's exchange rate stands *relative to others*.

Bosworth (2004), Frankel (2005), Coudert and Couharde (2005), and Cairns (2005b) estimate the relationship between the deviation from absolute PPP and relative per capita income. All obtain similar results regarding the relationship between the two variables (although Coudert and Couharde fail to detect this link for the RMB in their time series analysis).

Zhang (2001), Wang (2004), and Funke and Rahn (2005) implement what could broadly be described as behavioral equilibrium exchange rate (BEER) specifications.[3] These models incorporate a variety of channels through which the real exchange rate is affected. Since each author selects different variables to include, the implied misalignments will necessarily vary. In addition, these approaches will fail to identify whether a currency is misaligned relative to another country's for the same reason that relative PPP fails to do so – because they typically rely upon price indices but not actual prices.

Other approaches center on flow equilibria, considering savings and investment behavior and the resulting implied current account. The equilibrium exchange rate is derived from the implied medium term current account using import and export elasticities. In the IMF's "macroeconomic approach", the "norms" are estimated, in the

[2] This Chart is drawn from Cheung et al. (forthcoming).
[3] Also known as BEERs, a composite of exchange rate models.

spirit of Chinn and Prasad (2003). Wang (2004) discusses the difficulties in using this approach for China but does not present estimates of misalignment based upon this framework. Coudert and Couharde (2005) implement a similar approach. Finally, the external balances approach relies upon assessments of the persistent components of the balance of payments condition (Goldstein, 2004; Bosworth, 2004). This last set of approaches is perhaps most useful for conducting short-term analyses. But the wide dispersion in implied misalignments reflects the difficulties in making judgments about what constitutes persistent capital flows. For instance, Prasad and Wei (2005), examining the composition of capital inflows into and out of China, argue that much of the reserve accumulation that has occurred in recent years is due to speculative inflow; hence, the degree of misalignment is small.[4]

In his survey, Cairns (2005a) observes that studies implementing an absolute PPP methodology result in the greatest degree of estimated undervaluation. Those implementing either relative PPP or flow equilibrium approaches find smaller estimates of undervaluation.

To highlight the drawbacks of this oft-used relative PPP approach, we examine briefly what this methodology says about the RMB.

2.2 Bilateral and Effective Exchange Rate Indexes

Figure 1 depicts the official exchange rate series from January 1987 to May 2006, deflated by the CPI's of the US and China. The rate is expressed so higher values

[4] Moreover, such judgments based upon flow criteria must condition their conclusions on the existence of effective capital controls. This is an obvious—and widely acknowledged — point, but one that bears repeating and, indeed, is a point that we will return to at the end of this paper.

constitute a stronger Chinese currency (the units of currency are denoted as CNY, for Chinese Yuan). In line with expectations, in the years since the East Asian crisis, the RMB has experienced a downward decline in value.

However, as with the case with many economies experiencing transitions from controlled to partially decontrolled capital accounts and from dual to unified exchange rate regimes, there is some dispute over what exchange rate measure to use. It turns out that in the years leading up to 1994, increasingly large amounts of RMB transactions were taking place at "swap rates" – rather than the official rate – so that the 1994 "mega-devaluation" is actually better described as a unification of different rates of exchange (Fernald, et al., 1999).

In the early warning system literature that developed in the wake of the financial crises of the 1990's, a typical measure of currency misalignment was the deviation from a deterministic trend. Using the "adjusted" rate, and fitting a linear time trend, one finds a modest undervaluation in the May of 2006 of 1.3%, contrasting slightly with the 5% *over*valuation implied by the official exchange rate.

In general, trade weighted exchange rates provide better measures of relative prices. However, using this same methodology on this exchange rate does not necessarily clarify matters.[5] Figure 2 depicts the IMF's trade weighted effective exchange rate index, and a linear trend estimated over the available sample of 1980-2006. One finds that focusing on the deviations from a simple trend indicates the RMB is 30% *overvalued*. Of course, a quick glance at the data indicates that a simple trend is much too simplistic a characterization. Suppose instead that one assumed that the relevant period was 1987

[5] As a matter of principal, trade weighted rates are to be preferred to bilateral rates since the reliance on the latter can lead to misleading inferences about overall competitiveness.

onward; then a flat trend and zero misalignment would be the determination. The fact that working with simple straight line extrapolations can lead to such diverging conclusions suggests that we need to take a closer look at where the Chinese currency should stand, both over time and across countries.

3. Absolute Purchasing Power Parity

3.1 The Basic Real Exchange Rate – Income Relationship

As a first cut, we appeal to a simple, and apparently robust, relationship between the real exchange rate and per capita income. We will then elaborate the analysis by stratifying the data along other dimensions (level of development, time period), and by adding in other variables that might alter one's assessment of the fundamental equilibrium level of the exchange rate.

First, let us consider the basic framework of analysis. Consider the law of one price, which states that the price of a single good should be equalized in common currency terms (expressed in logs):

$$p_{i,t} = s_t + p^*_{i,t} \qquad (1)$$

where s is the log exchange rate, $p_{i,t}$ is the log price of good *i* at time *t*, and the asterisk denotes the foreign country variable. Summing over all goods, and assuming the weights associated with each good are the same in both the home country and foreign country basket, one then obtains the absolute purchasing power parity condition:

$$p_t = s_t + p^*_t \qquad (2)$$

where for simplicity assume *p* is a arithmetic average of individual log prices. As is well known, if the weights differ between home and foreign country baskets (let's say production bundles), then even if the law of one price holds, absolute purchasing power parity need not hold.

The "price level" variable in the Penn World Tables (Summers and Heston, 1991), and other purchasing power parity exchange rates, attempt to circumvent this problem by using *prices* (not price indices) of goods, and calculating the aggregate price level using the same weights. Assume for the moment that this can be accomplished, but that some share of the basket (α) is nontradable (denoted by N subscript), and the remainder is tradable (denoted by T subscript). Then:

$$p_t = \alpha p_{N,t} + (1-\alpha) p_{T,t} \tag{3}$$

By simple manipulation, one finds that the "real exchange rate" is given by:

$$q_t \equiv s_t - p_t + p_t^* = (s_t - p_{T,t} + p_{T,t}^*) - \alpha[p_{N,t} - p_{T,t}] + \alpha[p_{N,t}^* - p_{T,t}^*] \tag{4}$$

Rewriting, and indicating the first term in (parentheses), the intercountry price of tradables, as $q_{T,t}$ and the intercountry relative price of nontradables as $\omega_t \equiv [p_{N,t} - p_{T,t}] - [p_{N,t}^* - p_{T,t}^*]$, leads to the following rewriting of (4):

$$q_t = q_{T,t} - \alpha\omega_t \tag{4'}$$

This expression indicates that the real exchange rate can appreciate as changes occur in the relative price of traded goods between countries, or as the relative price of nontradables rises in one country, *relative to another*. In principle, economic factors can affect one or both.

Most models of the real exchange rate can be categorized according to which specific relative price serves as the object of focus. If the relative price of nontradables is key, then the resulting models – in a small country context – have been termed “dependent economy” (Salter, 1959, and Swan, 1960) or “Scandinavian” model. In the former case, demand side factors drive shifts in the relative price of nontradables. In the latter, productivity levels and the nominal exchange rate determine the nominal wage rate, and hence the price level and the relative price of nontradables. In this latter context, the real exchange rate is a function of productivity (Krueger, 1983: 157). Consequently, the two sets of models both focus on the relative nontradables price, but differ in their focus on the source of shifts in this relative price. Since the home economy is small relative to the world economy (hence, one is working with a one-country model), the tradable price is pinned down by the rest-of-the-world supply of traded goods. Hence, the “real exchange rate” in this case is (p^N-p^T).

By far dominant in this category are those that center on the relative price of nontradables. These include the specifications based on the approaches of Balassa (1964) and Samuelson (1964) that model the relative price of nontradables as a function of sectoral productivity differentials, including Hsieh (1982), Canzoneri, Cumby and Diba (1999), and Chinn (2000). They also include those models that search more broadly and include demand side determinants of the relative price, such as DeGregorio and Wolf (1994), who observe that if consumption preferences are not homothetic and factors are not perfectly free to move intersectorally, changes in per capita income may result shifts in the relative price of nontradables.

This perspective provides the key rationale for the well-known positive cross-sectional relationship between the relative price (the inverse of q, i.e., $-q$) and relative per capita income levels. We exploit this relationship to determine whether the Chinese currency is undervalued. Obviously, this approach is not novel; it has been implemented recently by Coudert and Couharde (2005) and Frankel (2006). However, we will expand this approach along several directions. First, we augment the approach by incorporating the time series dimension.[6] Second, we explicitly characterize the uncertainty surrounding our determinations of currency misalignment. Third, we examine the stability of the relative price and relative per capita income relationship using a) subsamples of certain country groups and time periods, and b) control variables.

Before proceeding further, it is important to be explicit about the type of equilibrium we are associating with our measure of the "normal" exchange rate level. Essentially, the equilibrium exchange rate measure we identify is the one consistent with internal balance (resources in the nontradables and tradables sectors are fully utilized), taking as given that the external accounts are also balanced. In this respect, it is ill suited (on its own) to analyze short run contexts wherein trade balances should fluctuate to consumption smoothing and business cycle considerations.[7]

We amass a large data set encompassing up to 158 countries, over the 1975-2004 period. (Because some data are missing, the panel is unbalanced.) Most of the data are drawn from the World Bank's *World Development Indicators* (*WDI*). Greater detail on the data used in this subsection and elsewhere is reported in Appendix 1.

[6] Coudert and Couharde (2005) implement the absolute PPP regression on a cross-section, while their panel estimation relies upon estimating the relationship between the relative price level to relative tradables to nontradables price indices.

[7] For greater detail, see Frankel's (2006) discussion of whether one can speak of an "equilibrium exchange rate" when there is more than one sector to consider. Here we implicitly assume equilibrium in external balances so that the real exchange rate is that which sets internal balance.

Extending Frankel's (2006) cross section approach, we estimate the real exchange rate-income relationship using a pooled time-series cross-section regression, where all variables are expressed in terms relative to the US.

$$q_t = \beta_0 + \beta_1(y_t - n_t) + u_t \tag{5}$$

Where q is expressed in real terms relative the US price level, (y-n) is real per capita income.[8] The results are reported in Table 1, for cases in which we measure relative per capita income in terms of either market rates or PPP based exchange rates. Furthermore, to examine the robustness of the results with respect to different specifications, we report not only the pooled time-series cross-section estimates (our preferred specification) but also fixed effects and random effects models.

In either case, the elasticity of the price level with respect to relative per capita income is always around 0.25-0.30, which compares favorably with Frankel's (2006) 1990 and 2000 year cross-section estimates of 0.38 and 0.32, respectively.[9] Interestingly, the elasticity estimate does not appear to be sensitive to measurements of per capita income. In Figures 3 and 4, the actual and resulting predicted and standard error bands are reported.

One of the key innovations of our analysis is the central role accorded the quantification of the uncertainty surrounding the estimates. That is, in addition to

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[8] β_0 can take on currency specific values if a fixed effects specification is implemented. Similarly, the error term is composed of a currency specific and aggregate error if the pooled OLS specification is dropped.

[9] In addition to the obvious difference in the sample, our estimates differ from Frankel's in that we measure each country's (logged) real GDP per capita in terms relative to the US rather than in absolute terms. On the other hand, the absolute price on the left hand side is expressed relative to the US one. Hence, the resulting coefficient estimates are not necessarily directly comparable.

estimating the economic magnitude of the implied misalignments, we also show whether the implied misalignments are statistically different from zero.

In this context, we make two observations about these misalignment estimates. First, the RMB has been persistently undervalued by this criterion since the mid-1980s, even in 1997 and 1998, when China was lauded for its refusal to devalue its currency despite the threat to its competitive position.

Second, and perhaps most importantly, 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.

It is interesting to consider the path that the RMB has traced out in these graphs. It starts out the samples as overvalued, and over the next three decades it moves toward the predicted equilibrium value and then overshoots, so that, by 2003, it is substantially undervalued — by between 46% and 54% in level terms (greater in log terms) by these point estimates.

One aspect of estimating a pooled OLS regression is that it forces the intercept term to be the same across currencies, and assumes that the error term is distributed identically over the entire sample. Because this is something that should be tested, rather than assumed, we also estimated random effects and fixed effects regressions. The former assumes that the individual specific error is uncorrelated with the right hand side variables, while the latter is efficient when this correlation is non-zero. [10]

Random effects regressions do not yield substantially different results than those obtained using pooled OLS. Interestingly, when one allows the within and between coefficient to differ, one does find differing effects. In particular, with USD based per capita GDP, the within effect is much stronger than the between. This divergence is likely picking up short term effects, where output growth is correlated with other variables pushing up currency values. This pattern is not present in the PPP output based results, though.

Notice that the deviations from the conditional mean are persistent; this has an important implication for interpreting the degree of uncertainty surrounding these measures of misalignment. This suggests that deviations from the PPP-relative income relationship identified by the regression are persistent, or exhibit serial correlation. Frankel (2006) makes a similar observation, noting that half of the deviation of the RMB from the 1990 conditional mean exists in 2000. We estimate the autoregressive coefficient in our sample at approximately 0.89 to 0.91 (based on USD and PPP based per capita income figures, respectively) on an annual basis. A simple, *ad hoc* adjustment based upon the latter estimate suggests that the standard error of the regression should be adjusted upward by a factor equal to $[1/(1-\hat{\rho}^2)]^{0.5} \approx 2$.

To provide a temporal dimension of the estimated misalignment, we trace the evolution of the RMB level over time, its predicted value, and the associated confidence

[10] Since the price levels being used are comparable across countries, in principle there is no need to incorporate currency-specific constants as in fixed effects or random effects regressions. In addition, fixed effects estimates are biased in the presence of serial correlation, which is documented in the subsequent analysis.

bands adjusted to account for the serial correlation in Figure 5. To simplify the presentation, we focus on regressions using PPP-based output data henceforth.[11] The figure shows a striking feature – after controlling for serial correlation, the actual value of the RMB is always within one standard error prediction interval surrounding the (predicted) equilibrium value in the last 20 plus years! Combining this result and the large data dispersion observed in Figure 4, we have the impression that the data are not informative for a sharp misalignment inference – not just for the recent period but for the entire sample period.[12]

While the *ad hoc* adjustment procedure offers a more accurate assessment of the degree of uncertainty surrounding the predicted values of the model, it gives no information on the estimated PPP-relative income relationship that is free of serial correlation effects. In order to obtain estimates that are statistically correct in the presence of serial correlation, we implemented a panel version of the Prais-Winsten procedure.[13]

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[11] Results based on US dollar output data are qualitatively similar in the sense that the undervaluation estimates are always within their respective two standard error bands. These results are available upon request.

[12] Indeed, for the case presented in Figure 4, a time series plot of the undervaluation estimate and its prediction error band shows that the estimate is within the two standard error prediction band not just for the year 2004 but it is true for a very large portion of the sample period.

[13] In essence, the Prais-Winsten method is an efficient procedure that incorporates serial correlation into the estimation process. We also implemented the Arellano-Bond approach that introduces lagged dependent variables into the model to account for serial correlation. The validity of the Arellano-Bond depends on the use of "good" instruments and the assumption that the number of time series observation is greater than the number of cross-sectional variables. In the current case, the choice of instruments is a practical issue and the time series dimension is smaller than the number of economies. In any case, the Arellano-Bond result is qualitatively similar to the one based on the *ad hoc* AR1 adjustment – the procedure gives a much larger standard error for a comparable estimate of undervaluation estimate given in Figure 3. These results are not presented for brevity.

The results are reported in Table 2. The OLS estimate using PPP per capita income indicate a short run elasticity of 0.15, which is smaller than the one reported in Table 1. The implied rate of adjustment is about 0.93 and the implied long run elasticity is an implausibly high value of around 2. Relaxing the assumption that the errors are the same across time and individual countries (i.e., the random effects regression), we obtain a smaller short run and hence long run elasticity – 0.13 and 1.8 respectively.

Since the Hausman tests rejects the orthogonality of the constant and the right hand side variable, we also consider the fixed effects regression results. These indicate the cross-country elasticity as being 0.4 (that is the "between" effect), and the short run elasticity 0.04 (not significant). Nonetheless, in the case of US dollar output data, the fixed effects model gives a significant short run elasticity of 0.124.

Figure 6 shows the predicted exchange rate based upon the pooled estimates. Two observations are in order. First, for most of the sample period, the actual RMB value is within the one standard error prediction band – that is, the currency is insignificantly different from its predicted equilibrium value. The result is similar to the one depicted in Figure 5. Second, while the actual RMB value has been slightly below its predicted value since the 1997 Asian financial crisis year, the two values virtually have converged by 2004 and there is little indication of undervaluation. In fact, the 2004 actual value slightly exceeds the predicted one; suggesting an *over*valuation of 0.2 percent albeit statistically insignificant. The surprising result is a consequence of taking serial correlation seriously – that is dealing with the high degree of persistence in the real exchange rate over time.

That being said, most of the time, the actual exchange rate is within about one standard error of the predicted, suggesting that the case for overvaluation is about as strong (or weak) as the case for undervaluation. In other words, we can have little certitude about RMB misalignment using this oft-used cross-country relationship between the real rate and per capita income, once issues of serial correlation are seriously addressed.

It is known that if there is autocorrelation in the model, it is necessary to deal with it to avoid biased estimates and unreliable inferences. In the current exercise, Figures 5 and 6 handle serial correlation using two different approaches and result in similar inferences about RMB misalignment. Despite the apparent RMB undervaluation, both cases show that adjustment for serial correlation effects renders a much weaker case of a significantly undervalued RMB.

In the next two sections, we shift our attention to other factors that may affect the PPP-relative income relationship.

4. Subsample Analyses

4.1 Developed/Developing and Income Grouping Stratifications

In Table 3, the results obtained when the sample is broken up into developed versus developing countries are reported. Interestingly, we find that the pooled OLS estimate is much larger for the developed countries than for the developing. This is somewhat surprising, given the widespread belief that Balassa-Samuelson effects are more pronounced in developing countries. Furthermore, the F-test indicates that the GDP effects are significantly different across the two country groups.

We investigate further by estimating random effects models. For developed countries, the GDP effect under the random effects model is substantially smaller than the one under the OLS setting; 0.19 versus 0.75. The change in the case of developing countries is much less dramatic, and the random effects model gives a stronger GDP effect. Interestingly, the random effects specification reverses the relative size of the GDP effect so that now the slope coefficient is greater in developing countries. Since the Hausman test fails to reject the exogeneity assumption, we can be relatively confident that these values are representative.

Using the developing country pooled OLS estimates, we find that the RMB is 51% misaligned as of 2004 (see Figure 7). However, the actual is still within two standard errors of the predicted – and this is true even though in this case *we have not accounted for serial correlation at all.*

When we break the sample into finer categories -- namely into high, middle, and low income groupings – we find a pattern wherein the pooled OLS estimates are highest in the highest income group, and declines with income grouping (Table 4). A formal F-test confirms that the estimated GDP effects are significantly different across these income groups.

Moving to the random effects specifications, which appear to be appropriate for the high and middle income groupings, one finds that the elasticities are about the same, at 0.16 versus 0.14. Table 4 also shows the between effects' estimate of the exchange rate-income elasticity of -0.26 for low income countries, while the within effect is about a half. In other words, for low income countries, there is substantial variation over time due to income changes.

Using the middle income country estimates we calculate the estimate of RMB undervaluation close to 48% at 2004, but still within the two standard error band (see Figure 8).

4.2 The East Asian Economies

One question that stands out in our mind is whether East Asia as a whole is distinguished from other countries in terms of its experience with real exchange rates. In addition, we have some *a priori* idea that Africa at the very least behaves in a different way than other developing countries. Hence, we also stratify the sample by regional grouping. The estimation results in Table 5 and the F-test statistics in its Notes section provide some evidence that there are indeed significant regional differences.

Asia and Latin America do not differ substantially in terms of the pooled OLS estimates, while Africa's coefficient is somewhat lower. The random effects specification is rejected by Hausman tests; looking to the fixed effects regressions, we find the pattern mentioned in the previous section repeated. That is, in the relatively higher income Asia grouping, the between coefficient is fairly high, while the within is actually negative.[14] The Latin America grouping exhibits about equally sized coefficients, while for Africa, the within coefficient dwarfs the nonsignificant between coefficient. We conclude that it is important to differentiate between country groupings.

Using the Asia coefficients, we find obtain a 49% undervaluation for RMB, once again within the two standard error band (see Figure 9).

4.3 Different Sample Periods

A third dimension along which to break the sample is along the time dimension. In particular, we use a break point of 1989/90, approximately halfway through the full sample.

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[14] See Devereux (1999) for an early observation of this pattern.

The results reported in Table 6 are quite interesting. According to the OLS results, the slope coefficient is larger, by about 75%, in the more recent period. However, this result does not stand up to allowing for random effects. Since the Hausman test rejects in the second subsample, we discuss the fixed effects estimates, which indicate the between effect has indeed been quite strong over the last fifteen years, while the within effect is essentially zero. That is important, as we consider the fact that Chinese per capita income has been rising rapidly over time. These results suggest that the average per capita income is what is important in assessing under or overvaluation. Using the pooled OLS estimate results, we find the RMB is undervalued by 67% (Figure 10).

Even though our sample stratification scheme is not exhaustive; the results so far inspire two general observations. One is that the GDP effect in the PPP-relative income regression varies across country groups and across historical periods. Second, the focus on these subsamples does not change the basic message developed in the last section – that is, the case for RMB is not that strong once sampling uncertainty is accounted for.

5. Beyond the Bivariate Framework

5.1 *Demographics, Policy and Financial Development*

One remarkable feature of the previous results is the finding that the RMB is almost always undervalued by close to 50% in log terms, no matter the sample used to make the assessment. This suggests that one might want to broaden the set of determinants.

Once one moves away from the idea of a simple world where the per capita income differential proxies for Balassa-Samuelson effects, a whole universe of additional determinants suggest themselves. In particular, if the income variable proxies not only for productivity differentials, but also non-homotheticity of preferences, savings propensities, or impediments to the free flow of capital, then one would wish to include variables that pertain to these factors. Hence we augment the relative per capita income with demographics – under 14 and over 65 dependency ratios – and with an index of capital account openness developed by Chinn and Ito (2006). We include a government deficit variable because Chinn and Prasad (2003) find that it explains part of current account balances over the medium term. Finally, financial deepening is proxied by an M2/GDP ratio.

The results are reported in Table 7. Interestingly, the elasticity of the price level with respect to relative income is not drastically altered, relative to the original full-sample bivariate regression estimates (Table 1). In addition, the additional variables enter in with statistical significance (with the exception of the government deficit variable).

Overall, the results suggest that capital account openness increases the value of the equilibrium value of the currency. Moreover, financial deepening also has a positive effect. This result does not appear to be the consequence of a spurious "credit boom" effect, since the "between" coefficient is more important than the "within" (or over time) coefficient.

The time profile of the implied RMB undervaluation, using the pooled OLS specification, is depicted in Figure 11. Nominal undervaluation greater than one standard error is observed starting 1994, the year China moved from a dual to a unified exchange rate arrangement. Nonetheless, the estimated degree of undervaluation is usually within the two standard error prediction band and is only slight outside the band in 2004. The actual RMB value is just outside the two standard prediction error band at the very end of the sample period; in this instance the undervaluation is 76%. Apparently, the inclusion of these additional explanatory variables tends to indicate greater misalignment.[15]

5.2 Per Capita Income, Capital Account Openness and Institutions

One oft-heard argument is that the Chinese economy is special -- namely it is one that is characterized by extreme corruption, as well as an extensive capital control regime. We investigate whether these two particular aspects are of measurable importance in the determination of exchange rates and, if so, whether our conclusions regarding RMB misalignment are altered as a consequence.

We augment the basic real exchange rate-relative income relationship with the aforementioned Chinn-Ito capital account openness index. In addition we use the *International Country Risk Guide*'s (ICRG) Corruption Index as our measure of institutional development (where higher values of the index denote less corruption).

The results are reported in Table 8. Since the corruption index is very slow moving, with a small time-varying component, it does not make too much sense to look at the fixed effects and random effects estimates. Focusing on the pooled estimates from PPP-based output data, one observes that the per capita coefficient is largely in line with the previous estimates. Similarly, capital account openness enters in positively, but not significantly. On the other hand, the (lack of) corruption enters in positively only when income is measured in PPP terms: The less corruption, the stronger the local currency.

In addition, we include an interaction term to allow for varying effects of capital openness in the presence of corruption. The estimates indicate that when capital account openness increases *in absence of corruption*, then the currency appreciates. This finding

[15] Although use of a fixed effects estimator indicates much smaller misalignment in this, and the subsequent, case.

implies that when the capital account openness increases in the presence of relatively high levels of corruption, the equilibrium value of the currency is weaker.

In Figure 12, the implications of the pooled regression estimates are drawn out. Interestingly, when the lack of corruption enters significantly in the specification, the resulting standard error bands are wider, and the estimated degree of undervaluation commensurately smaller. In log terms, the undervaluation in 2004 is somewhat smaller than in the previous case, 72%. In other words, to the extent that lack of transparency is given at an instant, the RMB is still not undervalued according to conventional levels of statistical significance. (Also, remember in none of these subsample analyses have we adjusted the standard errors for serial correlation.)

In sum, these control variables help explain a portion of the estimated undervaluation reported in the previous section. However, when sampling uncertainty is taken into consideration, we still end up with the same inference: there is no strong and consistent statistical evidence of RMB misalignment in the recent sample period. Rather, the actual RMB value is in almost every case within the corresponding prediction interval.

6. Summary and Some Concluding Thoughts

In the current exercise, we undertake an objective evaluation of the RMB undervaluation thesis using conventional empirical methods of inference. Anticipating the problems associated with using standard exchange rate models – including the FEER/BEER models commonplace in the practitioner literature – to explain exchange rate behavior of developing and transition economies, we opt to rely upon the more straightforward relative price and relative output framework.

We extend the existing literature along several dimensions. First, we analyze relative price and relative output relationship in a panel time-series cross-section framework in order to improve power, and so as to be able to trace out the time profile of misalignment measures. Second, we base our inferences on the property of misalignment estimates. In particular, we explicitly account for the effects of serially correlated errors and sampling uncertainty on our inferences regarding the extent of currency misalignment. Third, we examine the stability of the relative price and relative output relationship and the corresponding implications for the analysis of misalignments.

Under the basic specification and some of its variations, the RMB is found to be undervalued – a result that is consistent with the conventional wisdom. The undervaluation result, however, does not survive a close scrutiny of the empirical evidence.

One general observation is that, when one implements the standard operating procedure of accounting for sampling uncertainty in making inferences, there is no evidence supporting the claim that RMB is substantially undervalued, using conventional significance levels. Depending on the specification under examined, the actual RMB value is usually within one or two standard errors of its predicted level.

Our inability to establish a convincing statistically significant result applies to most, if not all, the models and time periods under consideration. One way to interpret these empirical results is that the data are not sufficiently informative.

We also believe that our results accounting for serial correlation are extremely important, and bear upon the interpretation of the extant literature. Once serial correlation effects are accounted for, the evidence for RMB understand is substantially weakened.

A by-product of our exercise is the finding that the relative price and relative output relationship is neither constant over time nor across groups. The variability of the output effect implies variously higher or lower misalignment estimates, but it does not alter the basic result that the empirical estimate is not significantly different from its predicted equilibrium value.

It is important to make it clear that we do not claim that the relative price and relative output relationship is the most appropriate framework for studying the RMB exchange rate behavior. Even though the framework we have adopted has certain advantages over some standard exchange rate models in cross-country analysis that involves transitional and developing economies, more effort has to be made to capture the special features of these economies. The addition of several control variables suggested by the literature may be a good first (empirical) step in the right direction. However, we admit that a more elaborate theoretical framework would be very helpful in guiding future work.

For instance, the finding that capital account openness and (the lack of) corruption matters for the level of the exchange rate suggests that our understanding of when a currency is misaligned is highly circumscribed. Other factors that warrant attention include the large buildup of nonperformance loans and the structural weakness of the financial sector. These factors, combined with corporate governance and labor market rigidity, are likely to have significant implications for the equilibrium value of RMB, not fully captured in the current exercise.

In closing, we freely admit that our analysis is not particularly sophisticated from either an econometric or theoretical perspective. We have simply highlighted how the conventional wisdom can be tempered by appealing to some basic points regarding empirical analysis and statistical inference, including serial correlation, sampling uncertainty, and model stability.

Although the presentation may give the impression we are diverting attention away from "reality" to mere statistics, we cannot stress enough the point that if we are to make a statement based on data, we have to make sure that inference is conducted appropriately. This point applies even more strongly when we consider the fact that we do not have assurance regarding the correct model of exchange rate valuation.

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Appendix 1: Data and Sources

For Section 2:

The nominal Renminbi exchange rate is the bilateral period average, expressed against the US$ (in $/f.c.u.), obtained from the IMF's *International Financial Statistics*, and from Hali Edison, for the "adjusted" exchange rates (Fernald et al., 1999). The CPI's are drawn from the CEIC database, extrapolated for 2004 and 2005 by using the CPI growth rates reported in *IFS*. The CPI deflated trade weighted exchange rate is drawn from *IFS*.

For Section 3:

The data for macroeconomic aggregates are drawn mostly from the World Bank's *World Development Indicators*. These include demographic variables, per capita income and government deficits. Financial development indicators, including lending, stock and bond market capitalization, are drawn from the Beck et al. (2000). The capital controls index is from Chinn and Ito (2006). The (inverse) corruption index is drawn from the *International Country Risk Guide*. Data for Taiwan are drawn from the Central Bank of China, International Centre for the Study of East Asian Development, and Asian Development Bank, *Key Indicators of Developing Asian and Pacific Countries*. For some variables, 2004 data are drawn from the IMF, *World Economic Outlook* (April) database.

Table 1: Panel Estimation Results of the Real Exchange Rate – Income Relationship for 1975-2004

	USD-based GDP per capita				PPP-based GDP per capita			
	Pooled OLS	Between	Fixed effects (Within)	Random effects	Pooled OLS	Between	Fixed effects (Within)	Random effects
GDP p.c.	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)
Constant	-0.016** (0.008)	-0.036 (0.050)	-	0.084 (0.042)	-0.134** (0.011)	-0.177** (0.061)	-	-0.204** (0.043)
Adjusted R^2	0.496	0.617	0.763	0.496	0.349	0.413	0.754	0.349
F-test for Homo. C			29.468**				42.647**	
Hausman Chisq(1)				11.873**				0.167
# of obs.	4018				4018			

Notes: Unbalanced panel of 160 countries × 30 years (1975-2004). **, * and # indicate 1%, 5% and 10% levels of significance, respectively. Heteroskedasticity-robust standard errors are in the parentheses.

Table 2: The Prais-Winsten estimator of the real exchange rate – income relationship for 1975-2004

	USD-based GDP per capita				PPP-based GDP per capita			
	Pooled OLS	Between	Fixed effects (Within)	Random effects	Pooled OLS	Between	Fixed effects (Within)	Random effects
GDP p.c.	0.198** (0.013)	0.298** (0.019)	0.124** (0.015)	0.195** (0.012)	0.147** (0.021)	0.396** (0.028)	0.036 (0.025)	0.132** (0.021)
Constant	-0.014** (0.003)	0.008 (0.005)	-	-0.015** (0.003)	-0.026** (0.002)	0.001 (0.004)	-	-0.027** (0.003)
Adjusted R^2	0.061	0.584	0.064	0.061	0.012	0.389	0.021	0.012
F-test for Homo. C			1.091				1.218*	
Hausman Chisq(1)				57.912**				39.384**
# of obs.	3958				3958			

Notes: Notes: Unbalanced panel of 160 countries × 30 years (1975-2004). The panel regression models are estimated on the transformed data according to the Prais-Winsten method to remove serial correlations. **, * and # indicate 1%, 5% and 10% levels of significance, respectively. Heteroskedasticity-robust standard errors are in the parentheses.
The AR1 coefficient estimates for the Prais-Winsten data transformation are: 0.928**(0.005) for the USD-based GDP per capita, and 0.951**(0.004) for the PPP-based GDP per capita.

Table 3: Developed and developing economies with the PPP-based per capita income

	Developed Economies				Developing Economies			
	Pooled OLS	Between	Fixed effects (Within)	Random effects	Pooled OLS	Between	Fixed effects (Within)	Random effects
GDP p.c.	0.749** (0.049)	0.898** (0.144)	-0.019 (0.073)	0.187* (0.076)	0.233** (0.008)	0.238** (0.035)	0.294** (0.032)	0.276** (0.019)
Constant	0.209** (0.016)	0.257** (0.053)	-	0.031 (0.038)	-0.298** (0.018)	-0.314** (0.083)	-	- 0.229** (0.052)
Adjusted R^2	0.330	0.665	0.569	0.330	0.192	0.266	0.670	0.192
F-test for Homo. C			18.536**				39.097**	
Hausman Chisq(1)				0.000				0.453
# of obs.	600				3229			

Notes: Unbalanced panel of 20 developed economies and 124 countries × 30 years (1975-2004). **, * and # indicate 1%, 5% and 10% levels of significance, respectively. Heteroskedasticity-robust standard errors are in the parentheses.
The F test result for equality of the slope coefficient between the two samples:
Test statistics = 119.931** ~ F(2,3825)

Table 4: High, middle, and low income countries with the PPP-based per capita income

	High income countries				Middle income countries				Low income countries			
	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 p.c.	0.519** (0.028)	0.650** (0.103)	0.097 (0.031)	0.156* (0.036)	0.249** (0.019)	0.243** (0.077)	0.122** (0.044)	0.137** (0.026)	-0.087** (0.031)	-0.261* (0.122)	0.504** (0.045)	0.414** (0.042)
Constant	0.127** (0.013)	0.178** (0.050)	-	-0.026 (0.032)	-0.384** (0.137)	-0.384** (0.137)	-	-0.562** (0.057)	-1.297** (0.100)	-1.889** (0.384)	-	0.207 (0.143)
Adjusted R^2	0.312	0.564	0.636	0.312	0.096	0.106	0.650	0.096	0.005	0.062	0.564	0.005
F-test for Homo. C			26.981**				40.087**				33.207**	
Hausman Chisq(1)				0.000				0.168				34.445**
# of obs.	875				1799				1330			

Notes: Unbalanced panel of 31 high income countries, 74 middle income countries, and 54 low income countries × 30 years (1975-2004). **, * and # indicate 1%, 5% and 10% levels of significance, respectively. Heteroskedasticity-robust standard errors are in the parentheses.
The F test result for equality of the slope coefficient between samples:
High vs. middle = 98.483** ~ F(2,2670)
High vs. low = 147.143** ~ F(2,2201)
Middle vs. low = 58.053** ~ F(2,3125)

Table 5: Asia, Africa, and Latin America with the PPP-based per capita income

	Asia				Latin America				Africa			
	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 p.c.	0.437** (0.018)	0.489** (0.065)	-0.227** (0.065)	0.009 (0.039)	0.392** (0.023)	0.412** (0.122)	0.288** (0.045)	0.303** (0.040)	0.085** (0.018)	0.053 (0.070)	0.487** (0.064)	0.389** (0.035)
Constant	0.031 (0.027)	0.092 (0.132)	-	-0.764** (0.096)	-0.027 (0.038)	0.007 (0.213)	-	-0.176* (0.087)	-0.653** (0.053)	-0.766** (0.210)	-	0.209# (0.118)
Adjusted R^2	0.537	0.724	0.824	0.537	0.206	0.255	0.705	0.206	0.015	-0.010	0.546	0.015
F-test for Homo. C			44.594**				50.684**				32.909**	
Hausman Chisq(1)				20.704**				0.512				3.384#
# of obs.	563				884				1147			

Notes: Unbalanced panel of 22 Asian countries, 31 Latin American countries, and 43 African countries × 30 years (1975-2004). **, * and # indicate 1%, 5% and 10% levels of significance, respectively. Heteroskedasticity-robust standard errors are in the parentheses. (The country classifications are as defined by WDI. Asia does not include "South Asia", and Africa does not include "Middle East and North Africa".)
The F test result for equality of the slope coefficient between samples (based on the pooled OLS results):
Asia vs. Latin America = 1.351 ~ F(2, 1443)
Latin America vs. Africa = 37.500** ~ F(2, 2027)
Asia vs. Africa = 89.698** ~ F(2, 1706)

Table 6: 1975-1989 and 1990-2004 sub-sample results with the PPP-based per capita income

	1975-1989				1990-2004			
	Pooled OLS	Between	Fixed effects (Within)	Random effects	Pooled OLS	Between	Fixed effects (Within)	Random effects
GDP p.c.	0.207** (0.009)	0.214** (0.032)	0.283** (0.046)	0.238** (0.024)	0.353** (0.008)	0.359** (0.026)	-0.004 (0.056)	0.230** (0.021)
Constant	-0.181** (0.017)	-0.190** (0.068)	-	-0.143* (0.055)	-0.118** (0.016)	$-0.118^{\#}$ (0.059)	-	-0.369** (0.051)
Adjusted R^2	0.209	0.251	0.781	0.209	0. 459	0.529	0.865	0.459
F-test for Homo. C			36.279**				43.766**	
Hausman Chisq(1)				1.266				20.287**
# of obs.	1757				2261			

Notes: Unbalanced panel of 131 countries × 15 years (1975-1989) and 159 countries x 15 years (1990-2004). **, * and # indicate 1%, 5% and 10% levels of significance, respectively. Heteroskedasticity-robust standard errors are in the parentheses.
The F test result for equality of the slope coefficient between the two samples:
Test statistics = 183.677** ~ F(2, 4014)

Table 7: Panel Estimation Results of the Absolute Purchasing Power Parity Plus: Demographics, Policy and Financial Development 1975-2004

	USD-based GDP per capita				PPP-based GDP per capita			
	Pooled OLS	Between	Fixed effects (Within)	Random effects	Pooled OLS	Between	Fixed effects (Within)	Random effects
GDP p.c.	0.251** (0.007)	0.259** (0.026)	0.415** (0.034)	0.278** (0.016)	0.257** (0.013)	0.236** (0.045)	0.286** (0.034)	0.264** (0.022)
POP14	0.357** (0.032)	0.390** (0.092)	0.050 (0.055)	0.167** (0.048)	0.302** (0.036)	0.373** (0.116)	0.035 (0.056)	0.123** (0.050)
POP65	0.259** (0.031)	0.216# (0.116)	0.342** (0.082)	0.134# (0.074)	0.340** (0.035)	0.289* (0.140)	0.422** (0.083)	0.283** (0.079)
KOPEN	0.082** (0.011)	0.054 (0.057)	0.047** (0.015)	0.060** (0.014)	0.127** (0.013)	0.112 (0.069)	0.042** (0.015)	0.059** (0.014)
GDEF	0.000 (0.000)	0.000* (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000* (0.000)	0.000 (0.000)	0.000 (0.000)
M2/GDP	0.226** (0.025)	0.306* (0.123)	0.196** (0.036)	0.173** (0.037)	0.360** (0.028)	0.615** (0.143)	0.244** (0.036)	0.246** (0.038)
Constant	-0.798** (0.062)	-0.846** (0.205)		-0.350** (0.116)	-0.995** (0.070)	-1.234** (0.241)		-0.654** (0.120)
Adjusted R^2	0.603	0.730	0.797	0.596	0.520	0.604	0.790	0.509
F-test for Homo. C			20.236**				26.697**	
Hausman Chisq(2)				40.671**				15.561**
# of obs.	2626				2626			

Notes: Unbalanced panel of 132 countries × 30 years (1975-2004). Import and government deficit (GDEF) are relative to GDP. **, * and # indicate 1%, 5% and 10% levels of significance, respectively. Heteroskedasticity-robust standard errors are in the parentheses.

Table 8: Panel Estimation Results of the Absolute Purchasing Power Parity Plus: Income, Capital Account Openness and Institutions 1975-2004

	USD-based GDP per capita				PPP-based GDP per capita			
	Pooled OLS	Between	Fixed effects (Within)	Random effects	Pooled OLS	Between	Fixed effects (Within)	Random effects
GDP p.c.	0.247** (0.006)	0.252** (0.025)	0.340** (0.047)	0.267** (0.014)	0.254** (0.011)	0.222** (0.042)	0.185** (0.042)	0.268** (0.022)
KOPEN	-0.041 (0.032)	-0.178 (0.169)	0.051 (0.033)	0.039 (0.031)	0.040 (0.037)	0.058 (0.209)	0.050 (0.033)	0.048** (0.032)
CORRUPT	0.063# (0.030)	-0.023 (0.162)	0.111** (0.028)	0.102** (0.031)	0.214** (0.042)	0.273 (0.202)	0.107** (0.029)	0.131** (0.031)
KOPEN* CORRUPT	0.159** (0.040)	0.362# (0.155)	0.006 (0.045)	0.022 (0.042)	0.174** (0.047)	0.275# (0.261)	0.007 (0.046)	0.025 (0.043)
Constant	-0.118** (0.033)	-0.071 (0.155)		-0.096# (0.052)	-0.419** (0.040)	-0.553** (0.189)		-0.334** (0.057)
Adjusted R^2	0.640	0.746	0.839	0.638	0.517	0.605	0.834	0.505
F-test for Homo. C			24.713**				37.878**	
Hausman Chisq(3)				3.026				18.213**
# of obs.	2111				2111			

Notes: Unbalanced panel of 111 countries × 30 years (1975-2004). **, * and # indicate 1%, 5% and 10% levels of significance, respectively. Heteroskedasticity-robust standard errors are in the parentheses.

Chart 1: Studies of the Equilibrium Exchange Rate of the Renminbi

	Relative PPP, Competitiveness	Absolute PPP-Income Relationship	Balassa-Samuelson (with productivity)	BEER	Macroeconomic Balance/External Balance
Time Series	Wang (2004) CCF (forthcoming)	Bosworth (2004)	CCF (forthcoming)	Zhang (2001) Wang (2004) Funke & Rahn (2005)	Bosworth (2004) Goldstein (2004) Wang (2004)
Cross Section		Coudert & Couharde (2005) Frankel (2005)			
Panel		Cairns (2005b) CCF (2005a)		CCF (forthcoming)	Coudert & Couharde (2005)

Notes: Relative PPP indicates that the real exchange rate is calculated using price or cost indices and that no determinants are accounted for. Absolute PPP indicates the use of comparable price deflators to calculate the real exchange rate. Balassa-Samuelson (with productivity) indicates that the real exchange rate (calculated using price indices) is modeled as a function of sectoral productivity levels. BEER indicates composite models using net foreign assets, relative tradable to nontradable price ratios, trade openness, or other variables. Macroeconomic Balance indicates cases where the equilibrium real exchange rate is implicit in a "normal" current account (or combination of current account and persistent capital inflows, for the External Balance approach). Source: Cheung et al. (forthcoming).

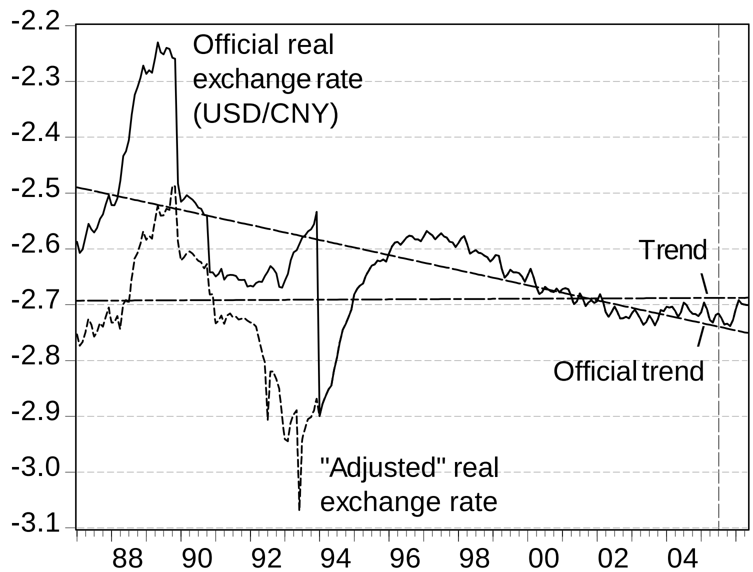

Figure 1: Real Chinese Exchange Rate, in logs (Official and "Adjusted") and Trends

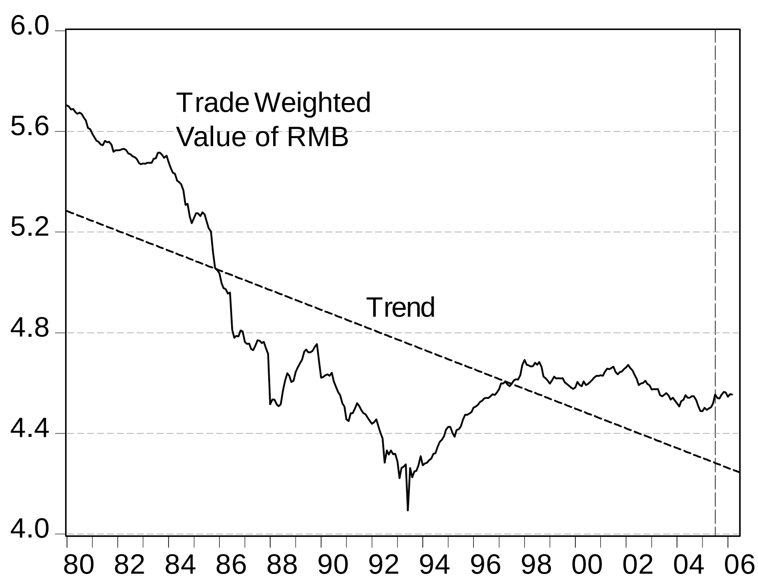

Figure 2: Real Trade Weighted Value of RMB, in logs, and Trend.

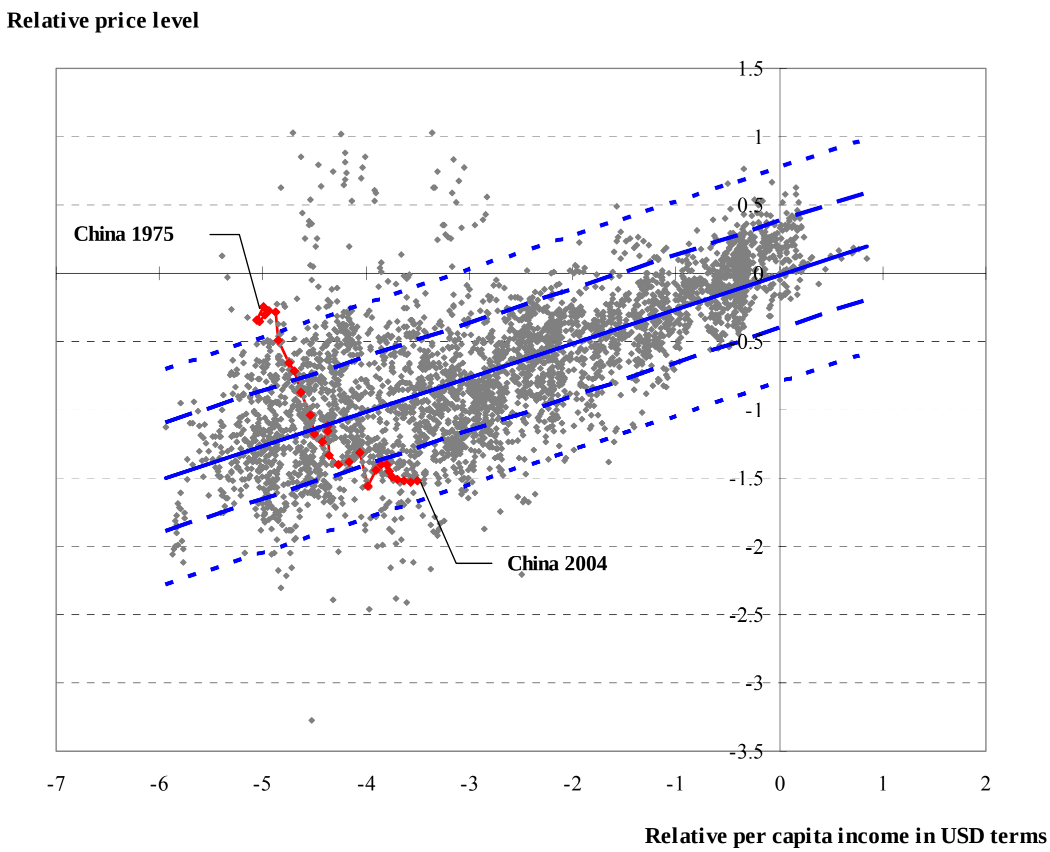

Figure 3: The rate of RMB misalignment based on the pooled OLS estimates with the USD-based per capita income

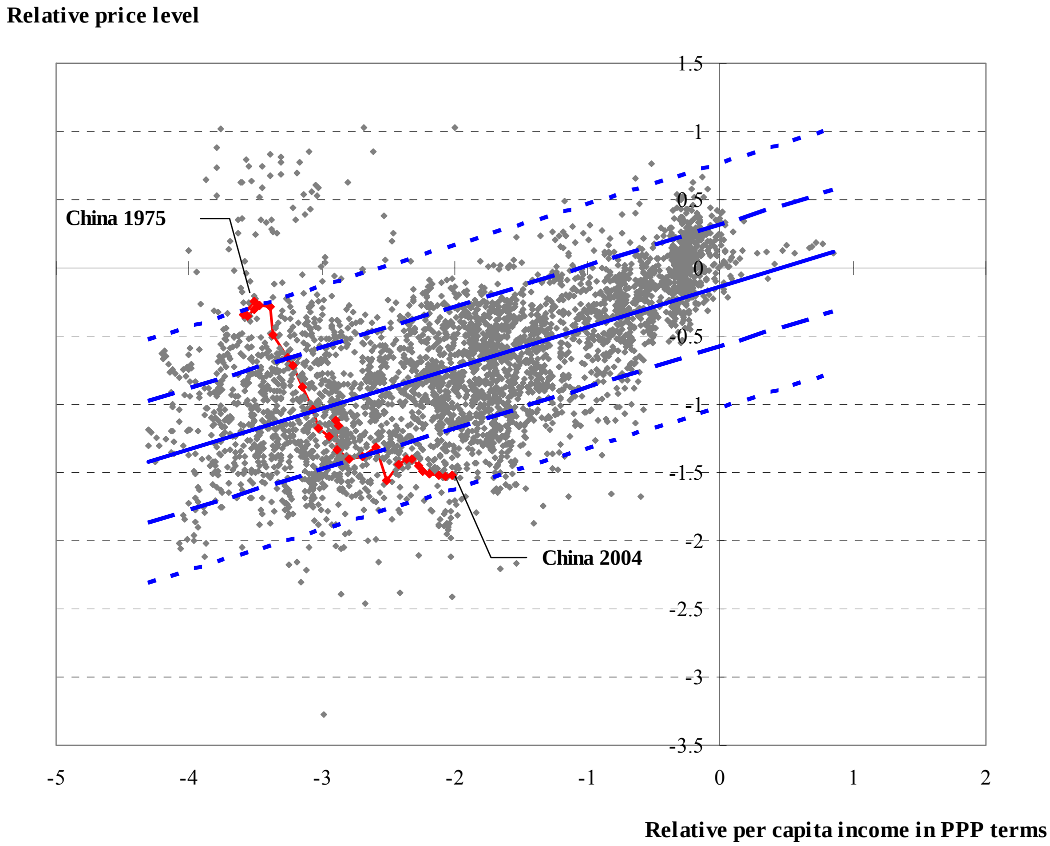

Figure 4: The rate of RMB misalignment based on the pooled OLS estimates with the PPP-based per capita income

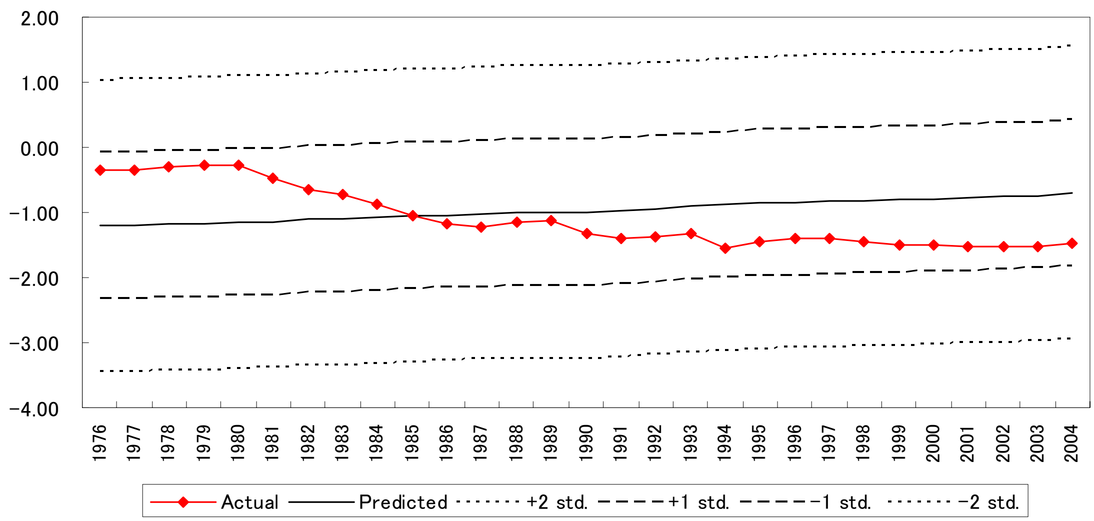

Figure 5: PPP-based real income, pooled OLS estimates with ad-hoc AR1 adjustment

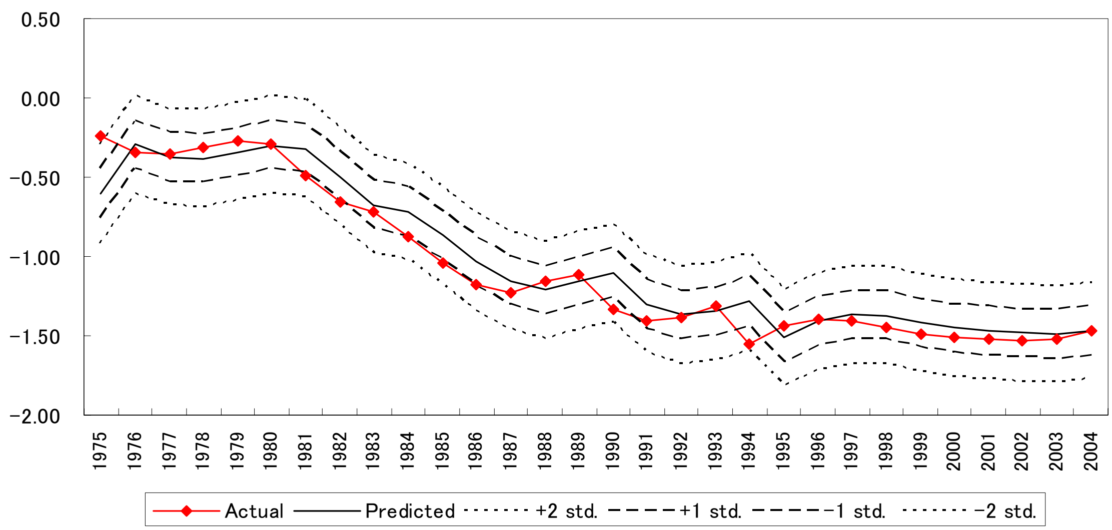

Figure 6: PPP-based real income, the Prais-Winsten estimates

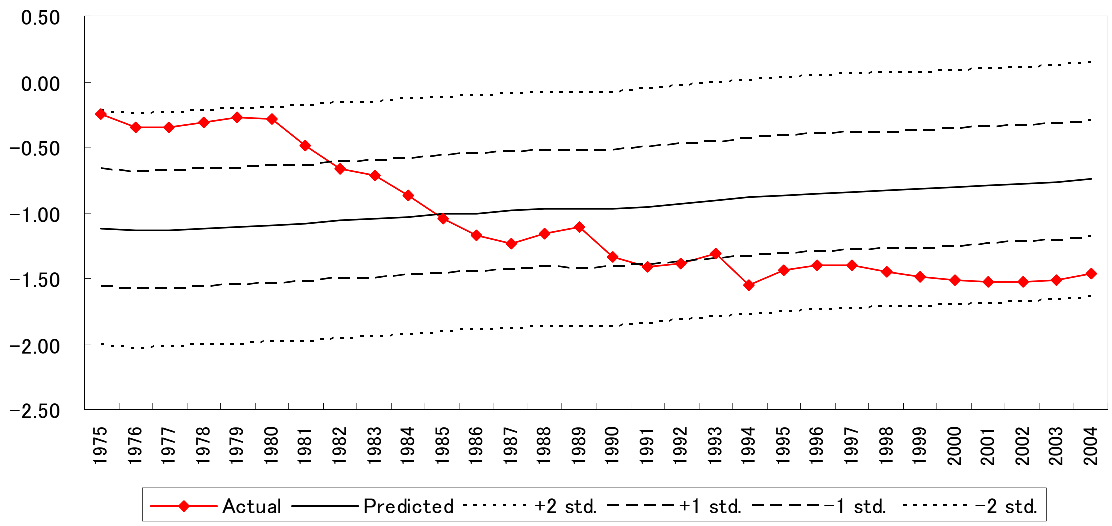

Figure 7: PPP-based real income, pooled OLS estimates with the less developed country sample

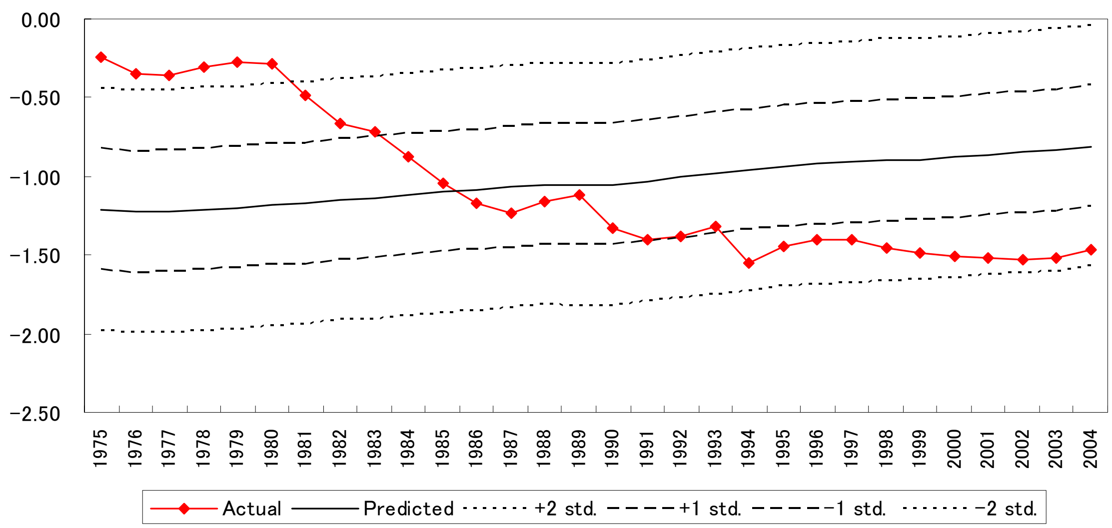

Figure 8: PPP-based real income, pooled OLS estimates with the middle income country sample

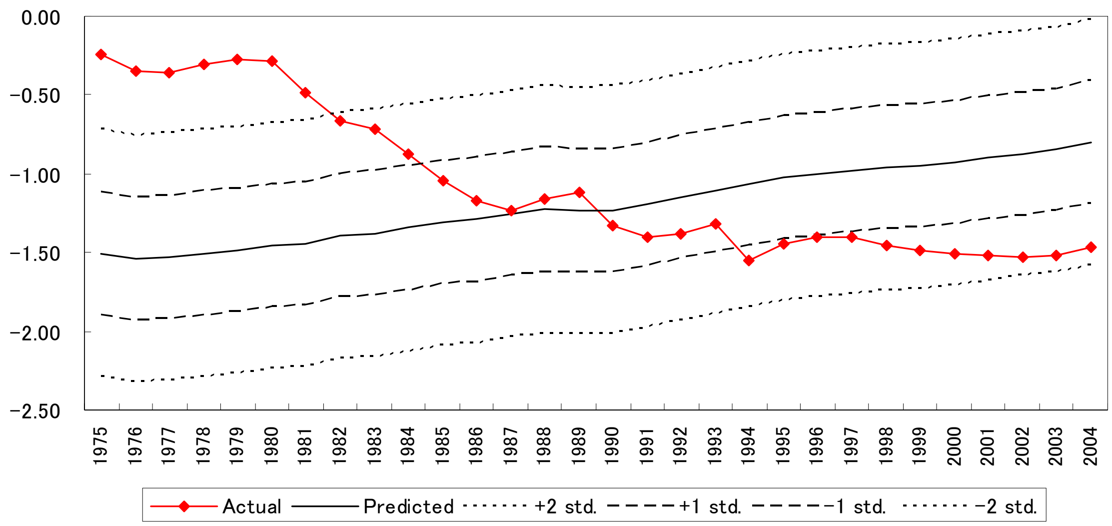

Figure 9: PPP-based real income, pooled OLS estimates with the East Asian country sample

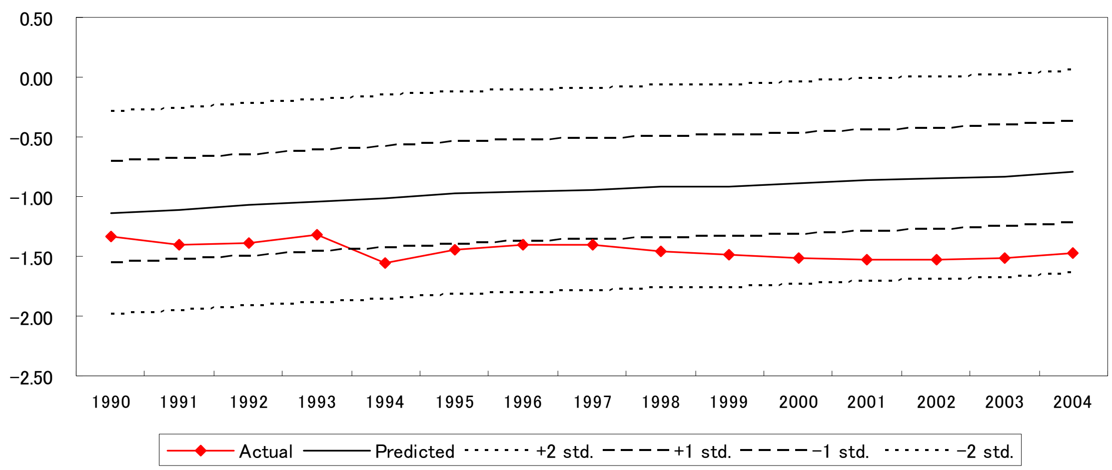

Figure 10: PPP-based real income, pooled OLS estimates with the 1990-2004 sample

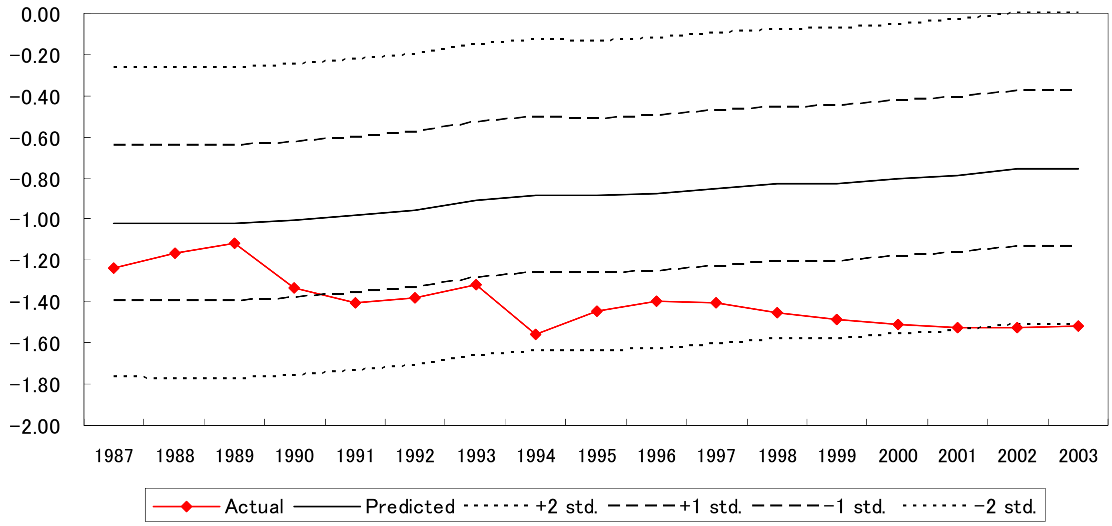

Figure 11: PPP-based real income, pooled OLS estimates with the demographics, policy and financial development as controls

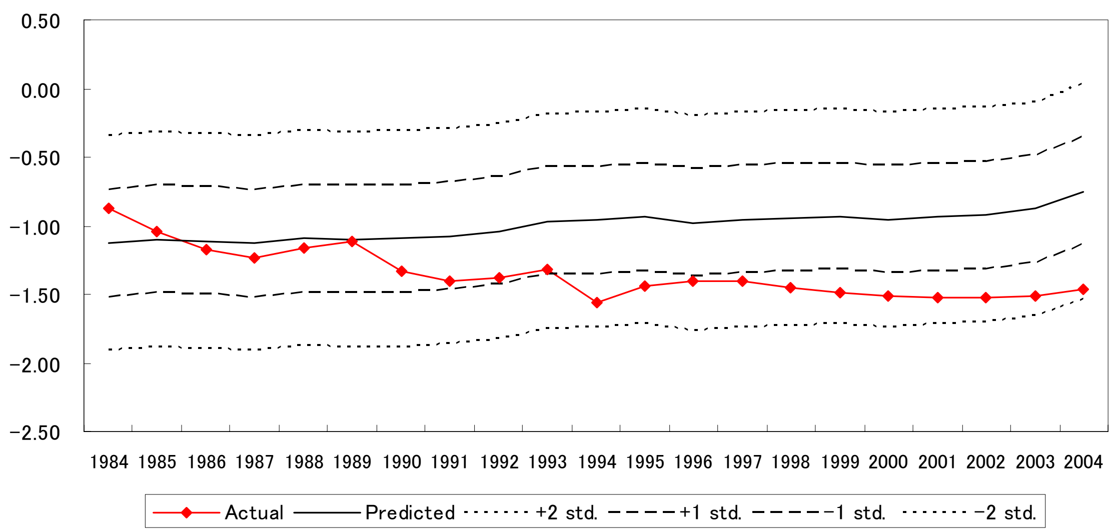

Figure 12: PPP-based real income, pooled OLS estimates with the capital account openness and institutions as controls