Journal of International Money and Finance 77 (2017) 18–38

Contents lists available at ScienceDirect

Journal of International Money and Finance

journal homepage: www.elsevier.com/locate/jimf

The PPP approach revisited: A study of RMB valuation against the USD

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ARTICLE INFO

Article history:
Available online 30 June 2017

JEL classification:
F31
F41

Keywords:
Renminbi
Currency misalignment
Penn effect

ABSTRACT

We analyze the alleged undervaluation of the Chinese renminbi against the US dollar through an application of the relative PPP hypothesis, the PPP approach. The PPP approach measures the relative misalignment of a currency by estimating the relationship between log price levels and log per capita real incomes from a cross section of countries. We estimate this relationship by using ICP 2011 and incorporating model selection tests. Our results confirm that price level-real income relationship is best approximated by a quadratic functional form. We show that, using this functional form, the PPP approach does not reveal any evidence of renminbi undervaluation as of 2011, and this result is robust to various sensitivity tests.

1. Introduction

China has a history of exchange rate regimes with strict capital controls and foreign exchange interventions. Although the Chinese government allowed for a gradual appreciation of the renminbi (RMB) between 2005 and 2015, it has been argued that China still limited the movement of its exchange rate to maintain a trade advantage over its trading partners.[1] The United States, China's leading trade partner, has made the most prominent allegations. They have long argued that the renminbi is significantly undervalued against the US dollar, and this undervaluation played a part in creating their large annual trade deficits with China (Morrison and Labonte, 2013). This argument was reemphasized by the United States Treasury Department in reports released in 2014, and 2015 (U.S. Department of the Treasury Office of International Affairs, 2014, 2015).

A much used approach to investigate whether a currency is undervalued against another is based on the relative purchasing power parity (PPP) hypothesis: in order to obtain a long run measure of the real exchange rates, the relationship between price levels[2] and per capita real incomes is estimated. The relationship has been estimated to be upward sloping, and this is referred to as the Penn effect (Samuelson, 1994; Rogoff, 1996). The theoretical arguments are given by the Balassa-Samuelson hypothesis predicting an upward sloping relationship. In this approach, currency misalignments are taken to be the difference between a country's observed price level and its predicted price level (see e.g. Rodrik, 2008). If the predicted price

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[1] In fact, in August 2015, China devalued the renminbi by around 3.5%. However this devaluation does not affect the discussion of this paper as we analyze the potential undervaluation in 2011.

[2] Let E, P and $P^{\star}$ denote the nominal exchange rate, local, and foreign aggregate prices, respectively. Then, the price level (PL) of a country, defined as $PL = PPP/E$, is equal to its real exchange rate (RER), $RER = P/EP^{*}$, by definition via the following relation: $P/EP^{*} = (P/P^{*})/E = PPP/E \iff RER = PL$.

http://dx.doi.org/10.1016/j.jimonfin.2017.06.006
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level is higher than the observed price level, the currency is considered overvalued, and vice versa. If there is no statistical difference between the estimated and the observed price levels, the currency is considered not to be misaligned.

In this paper, we revisit the PPP approach to currency misalignment, and discuss whether this approach provides any evidence for the alleged undervaluation of the renminbi against the US dollar in 2011 using ICP 2011. The PPP approach has previously been applied to analyze currency misalignments, and much of the literature has been devoted to the question of whether the renminbi is undervalued or not. A large strand of the literature argues that the renminbi has historically been undervalued against the US dollar. Most of this research is based on cross sectional data. Some examples are Frankel (2006), who uses cross sectional data from the Penn World Table 6.1 and suggests that the renminbi was undervalued by 36% in 2000, and Subramanian (2010), who uses ICP 2005, and suggests that the renminbi was undervalued by 30% in 2005. On the other hand, other researchers who use panel data sets suggest different results. For example, Zhang and Chen (2014) use a panel data set to test renminbi undervaluation and suggest that the renminbi was undervalued by 38% in 2011, however, if a control variable for net financial assets is included, then they conclude that the renminbi was overvalued by 8%. Cheung et al. (2007), by extending the cross sectional estimation that is used by Frankel (2006), apply the PPP approach on panel data and suggest that the undervaluation of the renminbi was not statistically significant in 2004. They also show that, if serial correlation is controlled for, renminbi undervaluation was never statistically significant between 1976 and 2004.

The standard way to estimate the price-income relationship has been to use a log-linear functional form, and to regress countries' price levels on their per capita real income levels. However, Hassan (2016) shows that this relationship is better approximated by a log-quadratic functional form. Independent research by Cheung et al. (2016) also analyzes the implications of this non-linearity in the Penn effect by estimating renminbi misalignment with a quadratic form, and show that the misalignment result may vary substantially depending on the data set regardless of the functional form.[3] Our analysis contributes to the ongoing debate. First we make use of the latest ICP round directly in a cross sectional analysis (see also Kessler and Subramanian, 2014), which arguably provides the most reliable PPP measure for China, account for a possible non-linearity with the suggested log-quadratic specification, and measure misalignment using statistical bounds on the price level estimates. Second, we present results with alternative estimations, such as kernel weighted local polynomials, and a principal component regression. This is in addition to more standard robustness checks using different control variables, such as net foreign asset positions, and sample stratifications.[4] Thus, our research provides a comprehensive analysis that includes different samples, functional forms, and estimation techniques. We select our preferred models using standard model selection tests and residual plots. Our results suggest that the preferred specifications provide no evidence for the alleged undervaluation of the Chinese renminbi as of 2011.[5]

Other approaches have been suggested and used to assess the alleged undervaluation of the renminbi.[6] For example, Bénassy-Quéré et al. (2004), Cline and Williamson (2010) use a fundamental equilibrium exchange rate (FEER) approach to assess the misalignment of the Chinese renminbi. Their findings suggest that the renminbi was undervalued by 44% in 2003 and by 41% in 2009, respectively. Cui (2013) uses a behavioral equilibrium exchange rate (BEER) approach with monthly data and suggests that renminbi undervaluation varied between 25% and 35% during the course of 2011. The IMF Consultative Group on Exchange Rates, by using different approaches, suggests that renminbi undervaluation was between 3% and 23% in 2011 (IMF, 2011).

As different methodologies and data sets can be used to study potential misalignment, and as different approaches sometimes yield different results, the search for a consensus on whether the renminbi is undervalued continues. We choose to use the PPP approach to study the alleged misalignment and consider this approach to be an important complement to alternative existing methodologies. The PPP approach, contrary to the other approaches, conducts a cross country analysis to estimate currency misalignments, and it has the benefit of being a general equilibrium approach that does not allow over or undervaluation of all exchange rates simultaneously (see e.g. Lee et al., 2008; Subramanian, 2010).

The rest of the article proceeds as follows. Section 2 describes ICP 2011, and discusses why it is more appropriate than previous releases of the International Comparison Program to assess exchange rate misalignments, especially for the renminbi. Section 3 summarizes the empirical methodology, and discusses the Balassa-Samuelson effect, which constitutes the theoretical foundation for the PPP approach. In Section 4, we report the results of our functional form and misalignment analysis. Section 5 presents sensitivity tests, and show that our main result is robust to a variety of controls including different data sets, additional variables, and sample stratifications of ICP 2011. Section 6 concludes.

2. Data

PPPs, per capita real incomes, and yearly average nominal exchange rates are obtained from ICP 2011 that is the latest release of the International Comparison Program, which is organized by the World Bank irregularly every few years in collaboration with various academic, statistical, and economic institutions. The program specifically aims to provide

[3] According to their results, as of 2011, PWT 8.1 suggests that the renminbi was fairly valued, World Development Indicators suggest that the renminbi was overvalued around 30%, and this difference holds for both log-linear and log-quadratic specifications.

[4] We also estimate misalignment of the renminbi with PWT 9.0, using expenditure data from ICP 2011, excluding oil exporters from our estimations, and grouping countries by income levels, temperatures, income inequality levels, and institutional quality levels.

[5] On the other hand, our estimation using PWT 9.0 confirms that the renminbi was undervalued in 2005, which is the previous benchmark year for the ICP.

[6] See Coudert and Couharde (2009) for a review.

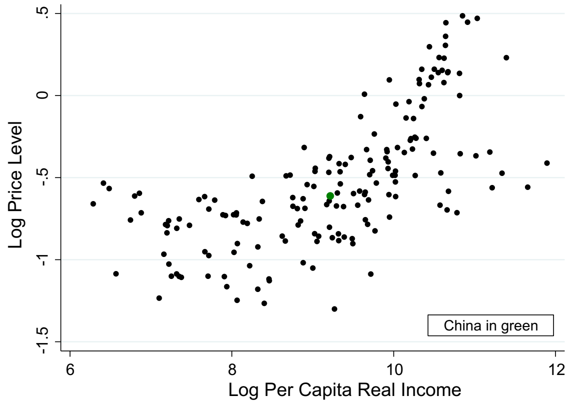


Fig. C.1. Price levels and per capita real incomes in ICP 2011.
Note: The figure displays the log price levels, calculated as the ratio of the PPP exchange rates to the nominal exchange rates, and the per capita real incomes of each country in ICP 2011. China is in the middle of the distribution, and is represented by a green data point. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

worldwide estimates of purchasing power parities to obtain an internationally comparable measure of price levels and real incomes. Fig. C.1 plots the relationship between price levels and per capita real incomes in ICP 2011.

ICP 2011, with its increased coverage, provides PPP exchange rates in various aggregate levels for 177 participating countries.[7] The data set also reports population sizes, nominal exchange rates, nominal GDPs, and their breakdown values for the participating countries. The PPPs that are provided in the International Comparison Program are based on localized price surveys. The remaining information is collected from the collaborating institutions, and countries' own national accounts.

ICP 2011 introduces several methodological improvements over the previous versions. As a result, the data provided by this latest release is argued to have a better quality (World Bank, 2014). Moreover, improvements in the representativeness of the underlying data, and in the estimation techniques are documented by several authors such as Deaton and Aten (2014), Inklaar and Rao (2017).

ICP 2011 addresses a major concern about previously available internationally comparable data on Chinese prices. This concern is a result of the lack of representativeness of Chinese data in ICP 2005, which caused a downward revision of China's real income level by 40% compared to its projections. These problems are caused by China's limited participation in the previous round of the International Comparison Program. In 2005, China participated in the price surveys with only 11 of its 34 provinces, and provided price data from only urban areas of these provinces. This limited participation resulted in a considerable urban bias in the Chinese price level (Hill and Syed, 2010). Supporting this argument, Deaton and Heston (2010) and Feenstra et al. (2013) argued that the Chinese price level was overestimated by about 20–30% in ICP 2005. However in 2011, China participated with 30 of its 34 provinces, and provided price data from both urban and rural areas (Asian Development Bank, 2014). As a result, ICP 2011 provides the most reliable internationally comparable Chinese price data as of date. To the best of our knowledge, we are the first to utilize this data to analyze whether the renminbi is undervalued against the US dollar.

In the sensitivity analyses, we make use of various other data sets. One of these data sets is a data set on country expenditure levels, which is provided by ICP 2011. The ICP data provides the aggregate expenditure level of each participating country, as well as the PPP exchange rates for expenditures. These expenditure levels are obtained from the participating countries' own national accounts. The PPP exchange rates for expenditures are constructed by using the same methodologies that are used to construct the standard PPP exchange rates. Explanations of all the other data sets we use is available in Appendix C. We report the results on the largest samples for which data are available.

3. Methodology

The standard way to apply the PPP approach is to estimate the relationship between price levels and per capita real incomes by using a log linear regression (Rogoff, 1996). This functional form is specified in Eq. (1) where PL_i is the ratio of the PPP exchange rate to the nominal exchange rate for country i, and $GDPP_i$ is the real gross domestic product (GDP) per capita.

$$ln(PL_i) = \beta_0 + \beta_1 ln(GDPP_i) + \varepsilon_i \quad (1)$$

Misalignment with the long run real exchange rate is calculated as the deviation from the estimated price level. In other words, percentage misalignment of the price level is the difference between log of its observed level and log of its predicted level if the difference is statistically significant.

[7] Our estimations that utilize the full sample have a sample size of 176 because the Cuban peso is not traded internationally.

$$\% misalignment = ln(PL_i) - ln(\hat{PL_i}) \quad (2)$$

However, as Hassan (2016) describes, a log linear relationship between real incomes and price levels is not empirically apparent. Therefore the standard log linear functional form may be misspecified. Hence we analyze the suitability of a log quadratic functional form as a more flexible functional form. To this end, we estimate a log linear functional form, as specified in Eq. (1), and a log quadratic functional form, as specified in Eq. (3), by applying an OLS regression with robust standard errors, and compare the results. Furthermore, an application with a nonparametric estimation can be found in Appendix A.

$$ln(PL_i) = \beta_0 + \beta_1 ln(GDPP_i) + \beta_2 ln(GDPP_i)^2 + \varepsilon_i \quad (3)$$

We test whether the log linear functional form is misspecified by applying model selection tests. We analyze the results of standard model comparison tests: a log-likelihood ratio test, Akaike, and Bayesian information criteria (AIC and BIC). A log likelihood ratio test analyzes if the parameter vector of an unconstrained model satisfies some smooth constraint by comparing its likelihood with that of a constrained model. If we reject the null hypothesis of the test, that is if the constraint is binding, then the preferred model is the unconstrained model. In our context, a rejection means that the log quadratic functional form is the preferred functional form. In case of AIC and BIC comparisons, we choose the model with the lowest criterion as the preferred model (Greene, 2012). We also report residual-regressor plots of each estimation to see whether there is a significant relationship between the residuals and the regressors.

As sensitivity tests, we conduct various analyses by considering the theoretical explanation for the expected positive relationship between price levels and per capita real incomes. The most prominent theoretical explanation is the Balassa-Samuelson hypothesis (Balassa, 1964; Samuelson, 1964), which explains the relationship through international differences in relative productivity between the tradable and the non-tradable sectors. The hypothesis states that price levels are lower in low-income countries because of their relatively lower productivity in the tradable goods sector. Balassa and Samuelson argue that the tradable sector is dominated by production of goods while the non-tradable sector is mainly comprised of services which cannot be exported. Prices of the tradable goods are therefore determined in the world markets, whereas prices of the non-tradable goods are determined domestically. Moreover, with perfect labor mobility between the tradable and the non-tradable sectors, wages are equalized, and they are paid according to the marginal productivity.[8] The hypothesis suggests that as a country develops, the marginal productivity of labor in the tradable sector increases relative to the marginal productivity of labor in the non-tradable sector as a result of technological spillovers and "know how" through international trade. Hence, the aggregate price of the non-tradable goods increases relative to the aggregate price of the tradable goods. Since the price level of a country is given by a combination of the prices of both its tradable and non-tradable goods, the country experiences an increase in its aggregate price level and hence an appreciation of its real exchange rate.

First, note that the Balassa-Samuelson hypothesis is a productivity based explanation for higher price levels in more developed countries. Given that prices in the tradable sector are exogenous, increasing productivity results in an increase in wages of the tradable sector, and subsequently an increase in the price level of the non-tradable sector. Although, in the literature, income is used to test this relationship, it is documented that expenditure data may be more reliable because of various measurement reasons (see e.g., Deaton, 1997; Meyer and Sullivan, 2011). Therefore, we include a robustness check where we analyze the relationship between log price level of expenditure and per capita real expenditures.[9]

Second, it is important to note that if the productivity increase in the tradable sector does not fully translate into higher prices in the non-tradable sector, the increase in the aggregate price level will be weaker. The Balassa-Samuelson hypothesis assumes that the translation occurs through wages in the tradable and the non-tradable sectors being equalized as a result of full labor mobility. However existence of wage differentials and imperfect sectoral labor mobility between the tradable and the non-tradable sectors have been documented in the previous literature (see, among others, Strauss and Ferris, 1996; Lee, 2006; Schmillen, 2013). As a result, countries may have very different price levels even if they have similar per capita income levels. This observation indicates that additional controls may be required to obtain a better price level prediction. We present additional sensitivity tests to account for this issue.

4. Results

A robust OLS estimation using the linear functional form suggests that the coefficient of log per capita real income is positive and significant ($p - value < 0.001$, see Table C.1). Log of the price level of China is estimated as −0.532 with a 95% confidence interval (−0.576, −0.489). The difference with the observed value suggests an 8% undervaluation of the Chinese renminbi compared to the US dollar as of 2011. Therefore, if we were to analyze only the outcome of the log linear functional form, we would conclude that the Chinese renminbi is undervalued against the US dollar in 2011. Fig. C.2 panels (a) and (b) graphically represent these results.

On the other hand, estimating the relationship between price levels and per capita real incomes with a robust OLS estimation using the log quadratic functional form suggests that the coefficients of log per capita real income and its squared are significant (see Table C.1). Log of the price level of China is estimated as −0.614 with a 95% confidence interval (−0.671,

[8] Wage in each sector is defined as the product of the marginal productivity of labor and the price level in that sector.

[9] Another way of conducting this analysis would be to instrument per capita real income using per capita real expenditure, and then regressing log price level of income on the predicted per capita income levels. Such an analysis yields very similar results in terms of misalignment.

Table C.1
OLS estimation results using income data.

	Linear	Quadratic
$ln(GDPP_i)$	0.216***	−0.732**
$ln(GDPP_i)^2$		0.053***
Constant	−2.522***	1.661*
$ln(\hat{PL}_{China})$	−0.532	−0.614
95% CI	(−0.576, −0.489)	(−0.671, −0.556)
% misalignment	−8.0%	No misalignment
R^2	0.448	0.497
Root MSE	0.299	0.286
Observations	176	176

***, **, * significant at 1%, 5% and 10%, respectively.
Note: $GDPP_i$ stands for the country *i*'s per capita real income. $\hat{PL}_{China}$ is the estimated price level of China. % misalignment is calculated as the difference between the log of the observed price level of China, which is −0.612, and the log of $\hat{PL}_{China}$ if the difference is statistically significant.

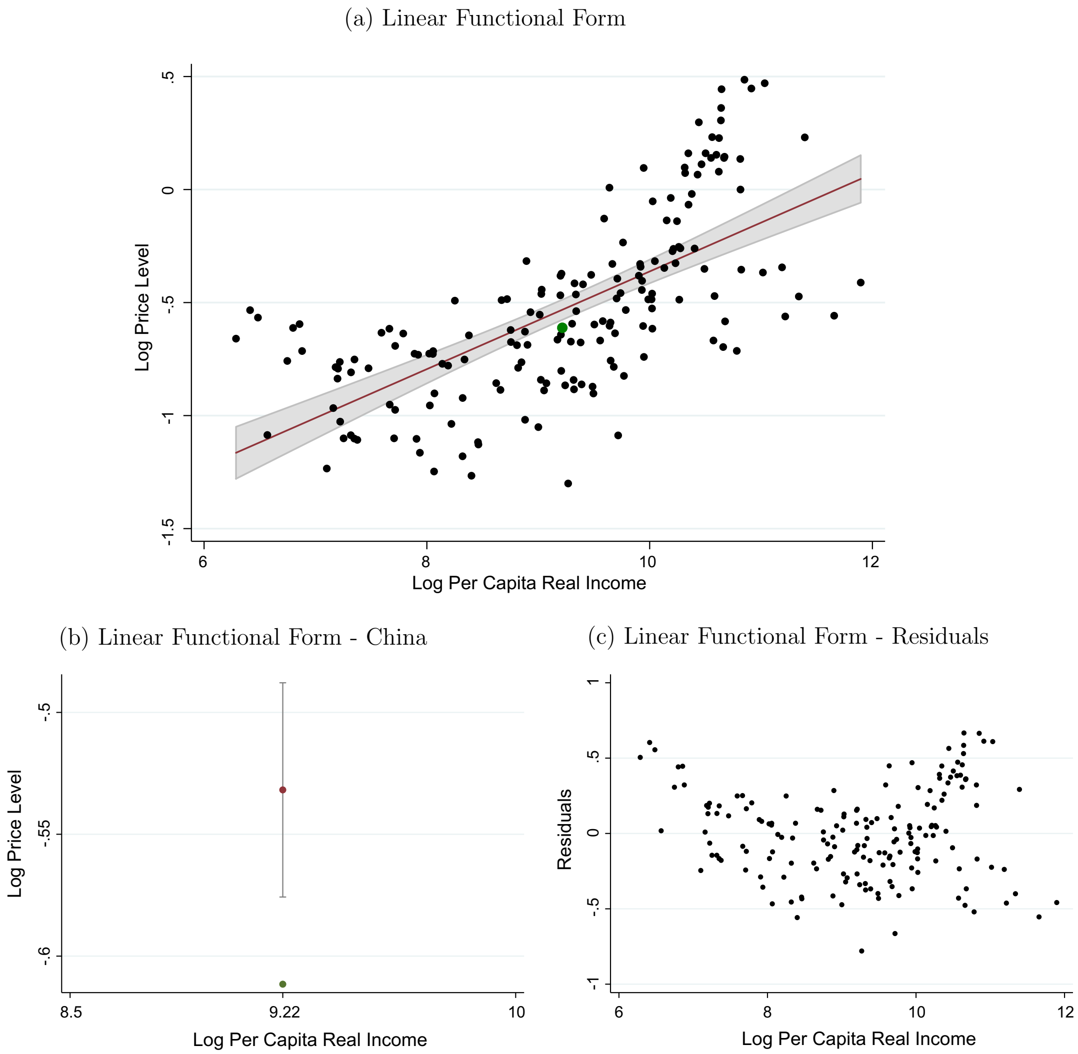


Fig. C.2. OLS estimation results using income data – 1.
Note: Panel (a) shows the estimated price levels in red, and the 95% confidence interval in gray. The observed price level of China is represented by the green data point. Panel (b) emphasizes the observed price level of China, the estimated price level of China, and the confidence interval. Panel (c) plots the residuals from the OLS estimation using the log linear functional form against the regressor. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

−0.556). Thus the observed price level of China falls within the confidence interval, and hence the renminbi is not undervalued as of 2011. Fig. C.3 panels (a) and (b) graphically represent these results.

Therefore the two functional forms yield different conclusions, and we need to determine which form better represents the relationship between price levels and per capita real incomes in ICP 2011. As the log linear functional form can be defined as a constrained form of the log quadratic functional form, we can use a log-likelihood ratio test to compare the two specifications. The result of the log-likelihood ratio test reports the test statistic as 16.40 which has a $\chi^2(1)$ distribution with a p-value indicating significant rejection of the null hypothesis that the coefficient of the quadratic term is zero ($p - value < 0.001$). Thus the log quadratic model is preferred. Other common tests for model selection includes checking Akaike information criterion (AIC) and Bayesian information criterion (BIC) for both models. Table C.2 summarizes these

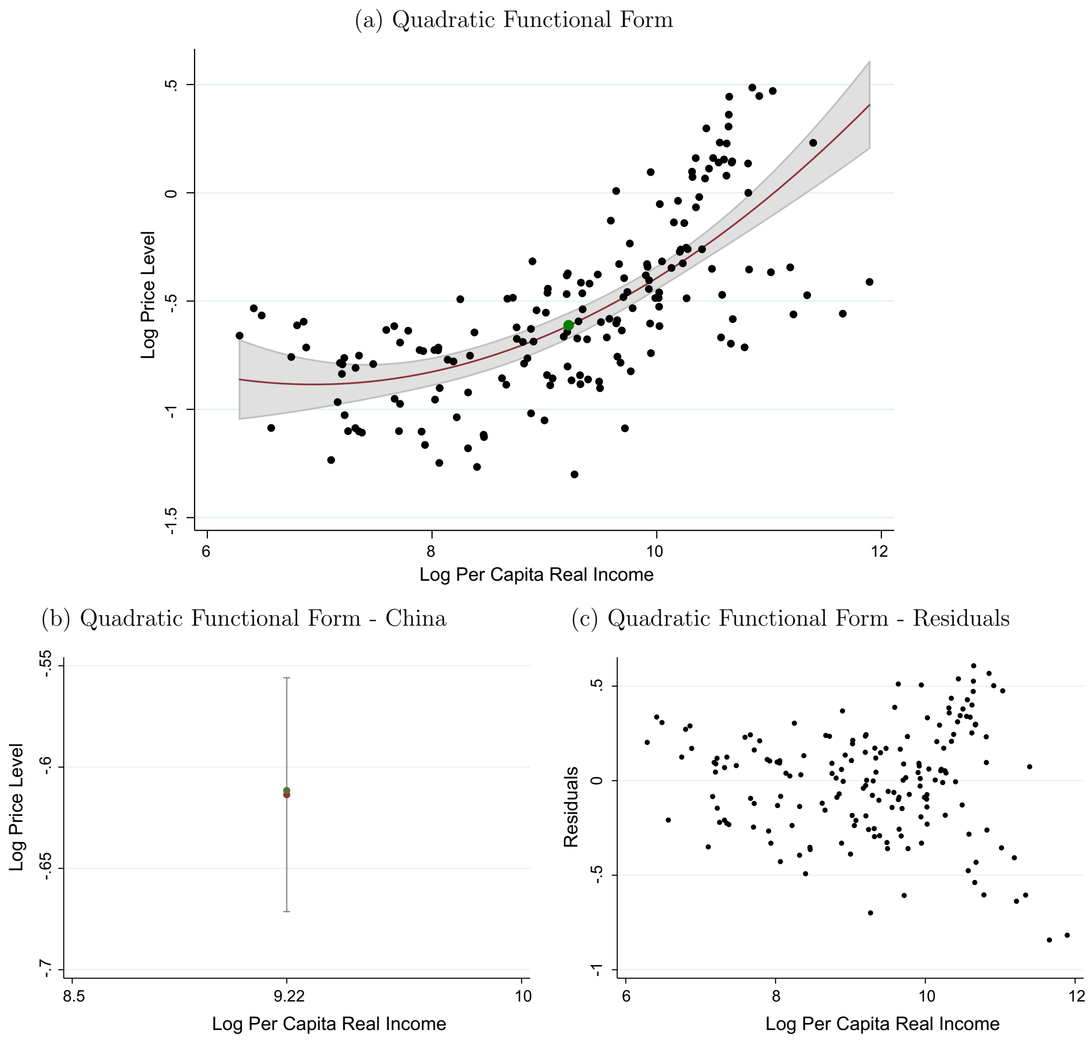


Fig. C.3. OLS estimation results using income data – 2.
Note: Panel (a) shows the estimated price levels in red, and the 95% confidence interval in gray. The observed price level of China is represented by the green data point. Panel (b) emphasizes the observed price level of China, the estimated price level of China, and the confidence interval. Panel (c) plots the residuals from the OLS estimation using the log quadratic functional form against the regressor. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table C.2
Model selection criteria using income data.

Functional form	AIC	BIC
Linear	76.549	82.890
Quadratic	62.146	71.657

Note: AIC stands for Akaike information criterion, and BIC stands for Bayesian information criterion. Both criteria suggest the functional form with the lowest score as the preferred functional form.

tests. Both criteria suggest that the log quadratic functional form is preferable. Therefore all tests reveal that the log quadratic functional form is preferred.

Yet another way to investigate how well a model represents the underlying relationship in the data is to analyze the residual plots. Fig. C.2 panel (c) plots residuals from the regression using the log linear functional form. According to the figure, residuals follow a nonlinear relationship with the regressors. On the other hand, Fig. C.3 panel (c) plots residuals from the regression using the log quadratic functional form. The residuals, except for those at the highest income quartile, show no significant relationship with per capita real incomes.

As we have shown, the results of the analysis depends on the functional form chosen for the estimation. An alternative route to the parametric one taken in the main analysis of this paper would be to use a nonparametric approach. Such an estimation also reveals that the Chinese renminbi is not undervalued as of 2011. Details of this nonparametric estimation are available in Appendix A.1.

5. Sensitivity analyses

In this section, we will first provide two sensitivity analyses to test the robustness of our results to sample selection. Then, we will discuss the results with various control variables and stratifications of ICP 2011.

5.1. Sensitivity to sample selection

5.1.1. The relationship between price levels and per capita real expenditures

Fig. C.4 plots log price levels of expenditures[10] and log per capita real expenditures.

Table C.3 summarizes the results of robust OLS estimations using both functional forms. All coefficients are significant ($p - value < 0.001$). Estimating the relationship between price levels and real expenditures by using the log linear functional form suggests no misalignment whereas using the log quadratic functional form suggests that the Chinese renminbi is 17% overvalued. Estimation results using both functional forms are presented in Figs. C.5 and C.6.

Therefore, similar to the results for the estimations using the relationship between price levels and per capita real incomes, the two functional forms suggest different conclusions. A log-likelihood ratio test, where the log linear model is nested in the log quadratic model, yields a test statistic of 47.37 which has a $\chi^2(1)$ distribution indicating significant rejection of the null hypothesis that the coefficient of the quadratic term is zero ($p - value < 0.001$). AIC and BIC of the log quadratic model are also lower. Therefore standard model selection tests suggest that the log quadratic functional form is the preferred functional form when we analyze the empirical relationship using expenditure levels as well (see Table C.4).

Moreover, Figs. C.5 panel (c) and C.6 panel (c) present the residual plots of the regressions for the two different functional forms. The log linear functional form reveals a nonlinear relationship whereas the log quadratic functional form reveals no significant relationship between the regressor and the residuals.

These analyses suggest that the log quadratic functional form is preferable when we estimate the relationship between price levels of expenditures and per capita real expenditures. The results confirm our main result that the Chinese renminbi is not undervalued against the US dollar in 2011.

5.1.2. The relationship between price levels and per capita real incomes - using the Penn World Table 9.0 (PWT 9.0)

The PWT provides a panel of PPP exchange rates for GDP and its components incorporating the current and the past ICP rounds (see Feenstra et al., 2015a). In the construction of the PWT, different techniques are used to obtain the PPP estimates,[11] and these estimates are extrapolated outside the benchmark years, which are the years without an ICP study, using country specific price indices from national accounts. In this latest release, that is the PWT 9.0, data from ICP 2011 is incorporated, the data from ICP 2005 is methodologically improved (Feenstra et al., 2015b; Inklaar and Rao, 2017), and the urban bias for the Chinese PPP estimates in ICP 2005 is accounted for (see Feenstra et al., 2013).

In our analysis, we will use the yearly cross section from PWT 9.0 to assess the misalignment of renminbi in 2011. Considering that the PWT 9.0 uses the benchmark data from ICP 2011, this analysis indicates whether the techniques used in obtaining PPP estimates affect our results. For the interested readers, PWT 9.0 also allows us to analyze the misalignment of renminbi in 2005, another benchmark year. Fig. C.7 shows the cross sections for the years 2005 and 2011 from PWT 9.0. We estimate the price-income relationship separately for each year using the corresponding cross sections, and thus refrain our analysis from the problems associated with PPP extrapolations based on national accounts (see e.g. McCarthy, 2013).[12]

For both years, the preferred functional form is the quadratic functional form. The results of the log-likelihood ratio tests suggest significant rejections of the null hypotheses that the coefficients of the quadratic terms is zero for both years (see

[10] Price levels of expenditures are calculated similarly by using *PPP* for individual expenditures instead of *PPP* for GDP.

[11] To obtain PPP estimates, ICP uses Gini-Éltetö-Köves-Szulc (GEKS) whereas PWT uses a combination of GEKS and Geary-Khamis (GK) aggregation techniques.

[12] Results for 1970-2014 can be provided upon request.

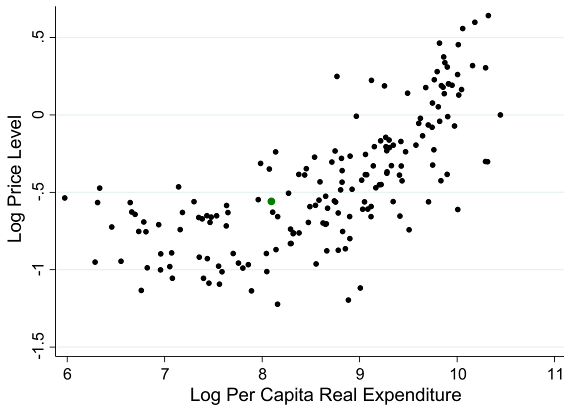


Fig. C.4. Price levels and per capita real expenditures in ICP 2011.
Note: The figure displays the log price levels of expenditures, calculated as the ratio of the PPP exchange rates for expenditures to the nominal exchange rates, and the per capita real expenditures of each country in ICP 2011. China is close to the middle of the distribution, and is represented by a green data point. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table C.3
OLS estimation results using expenditure data.

	Linear	Quadratic
$ln(exp_i)$	0.277***	−1.76***
$ln(exp_i)^2$		0.121***
Constant	−2.837***	5.553***
$ln(\hat{PL}^{exp}_{China})$	−0.593	−0.728
95% CI	(−0.641, −0.545)	(−0.785, −0.670)
% misalignment	No misalignment	17%
R^2	0.506	0.623
Root MSE	0.293	0.257
Observations	176	176

*** significant at 1%.
Note: exp_i stands for the country i's per capita real expenditure. $\hat{PL}^{exp}_{China}$ is the estimated price level of expenditure for China. % misalignment is calculated as the difference between the log of the observed price level of expenditure for China, which is −0.558, and the log of $\hat{PL}^{exp}_{China}$ if the difference is statistically significant.

also Table C.5 for AIC and BIC tests).[13] The results suggest that the renminbi is not undervalued against the US dollar in 2011, confirming our main analysis with ICP 2011. However, the renminbi is estimated to be 40% undervalued in 2005.[14] Figs. C.8 and C.9 graphically represent these results.

5.2. Additional sensitivity analyses

In this section, we would like to further analyze the robustness of our result to the addition of various control variables, and stratifications of ICP 2011.[15]

Our first analysis is related to the assumption that the Balassa-Samuelson hypothesis rests upon, which is the full labor mobility. One difficulty in incorporating the degree of sectoral labor mobility into our estimation is that it is unobservable. Artuc et al. (2015) show that the cost of labor mobility is negatively correlated with various educational indicators.[16] Therefore, mean years of education may be a proxy to account for the degree of sectoral labor mobility. This analysis reports that the renminbi is not undervalued against the US dollar as of 2011.

Another control may be applied by incorporating net foreign asset positions. Zhang and Chen (2014) show that the undervaluation of the Chinese renminbi, which they obtain by using the PPP approach and a panel of 19 large economies, is not

[13] The BIC test reports very similar values for both functional forms in 2005, and the log-likelihood ratio test report a p-value of 0.026, which suggests a significance rejection of the null hypothesis that the coefficient of the quadratic term is zero at 5% level of significance. The significance of the quadratic term is stronger if the analyses is repeated with a sub-sample that does not include some high income outlier countries that does not exhibit the Penn effect. If so, the renminbi is estimated 33% undervalued as of 2005. The quadratic functional form and the result for 2011 is robust to this change.

[14] The linear specification suggests that the renminbi was undervalued by 56% in 2005, and by 10.2% in 2011.

[15] We report the results of all estimations. Details of some of these analyses are in Appendix A. Details of the other analyses can be made available upon request.

[16] See Fig. C.10 for the relationship between labor mobility costs, as estimated by Artuc et al. (2015), and mean years of education for 2011 from our education data set, which confirms their analyses.

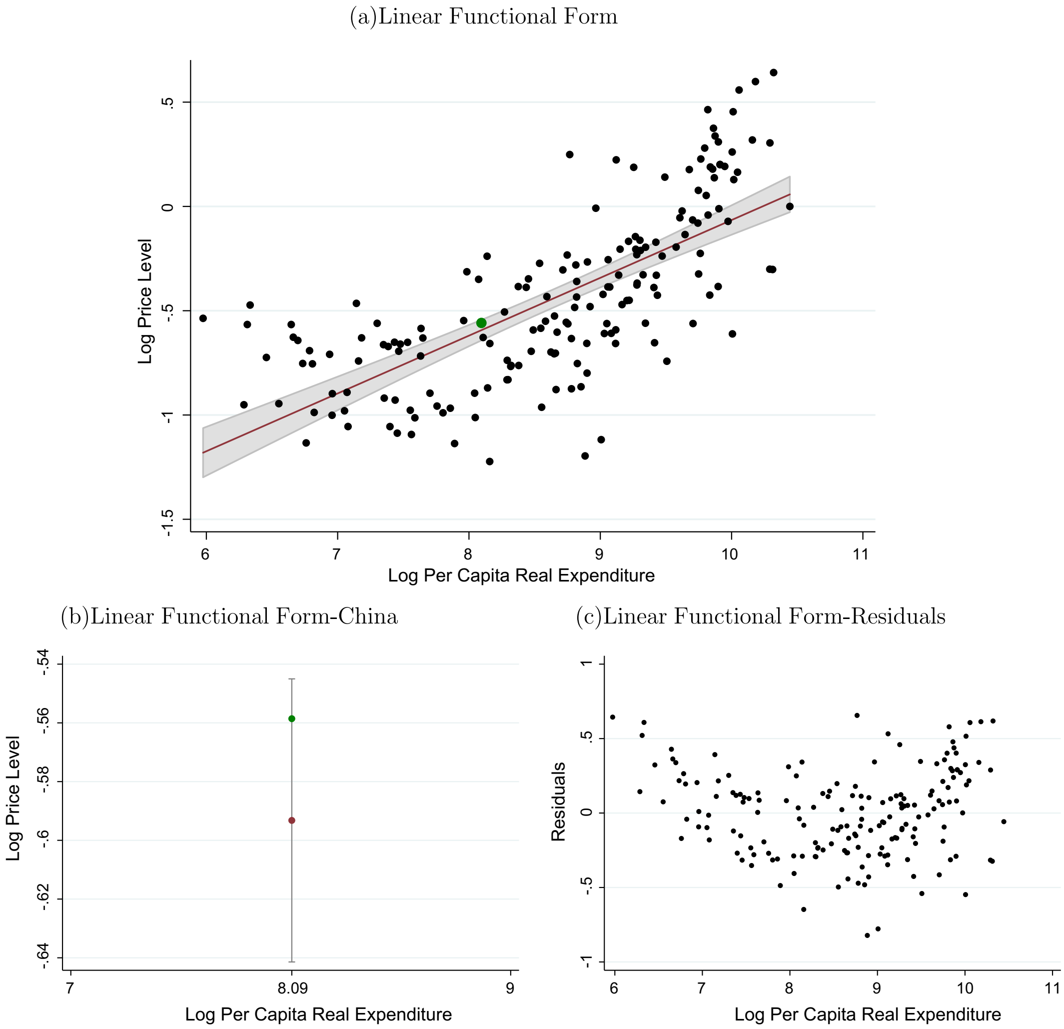


Fig. C.5. OLS estimation results using expenditure data – 1.

Note: Panel (a) shows the estimated price levels of expenditures in red, and the 95% confidence interval in gray. The observed price level of expenditure for China is represented by the green data point. Panel (b) emphasizes the observed price level of expenditure for China, the estimated price level of expenditure for China, and the confidence interval. Panel (c) plots the residuals from the OLS estimation using the log linear functional form against the regressor. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

robust to the addition of a control variable for net foreign asset positions. Moreover, Cline and Williamson (2008) suggest that controlling for financial variables, such as net foreign asset positions, is an improvement over the standard PPP approach. Our analysis[17] indicates the renminbi is not undervalued, showing that our initial result is robust to the inclusion of net foreign assets as a control variable.

Considering that the misalignment estimates are sensitive to the data at hand, we also test our result with different subsamples. One such subsample could be obtained with the exclusion of oil exporting countries because oil exporting economies may exhibit different dynamics between price levels and real incomes (see e.g., Korhonen and Juurikkala, 2009). Our analysis with the subsample that excludes the top oil exporters[18] shows that the renminbi is not undervalued against the US dollar, and confirms our initial analysis.

Other stratifications can be obtained by analyzing the renminbi in its own quartile and half of the world per capita income, average temperature, income inequality, and institutional quality distributions.[19] All of these results, as well as

[17] Net foreign asset positions of 154 countries as of 2011 are obtained from the World Bank.

[18] See Appendix C for a list of these countries.

[19] Income distribution is obtained over the per capita incomes as reported by ICP 2011. Note that China is very close to being in the third quartile. Our nonparametric analysis already provides an analysis for China's exact place in the distribution. Data sources for other groupings are provided in Appendix C. To obtain institutional quality, the first principle component of the five institutional indicators (see Appendix C) is used.

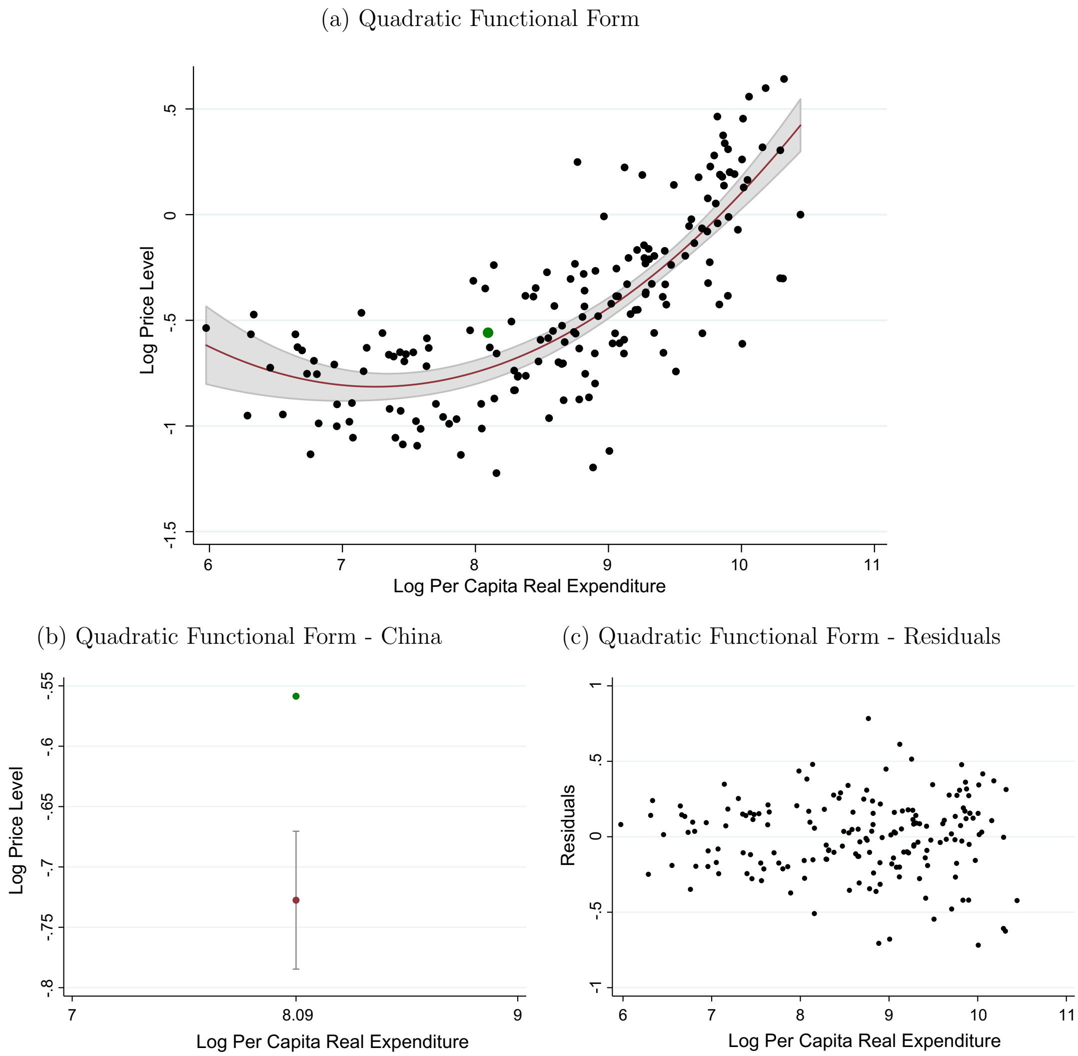


Fig. C.6. OLS estimation results using expenditure data – 2.
Note: Panel (a) shows the estimated price levels of expenditures in red, and the 95% confidence interval in gray. The observed price level of expenditure for China is represented by the green data point. Panel (b) emphasizes the observed price level of expenditure for China, the estimated price level of expenditure for China, and the confidence interval. Panel (c) plots the residuals from the OLS estimation using the log quadratic functional form against the regressor. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table C.4
Model selection criteria using expenditure data.

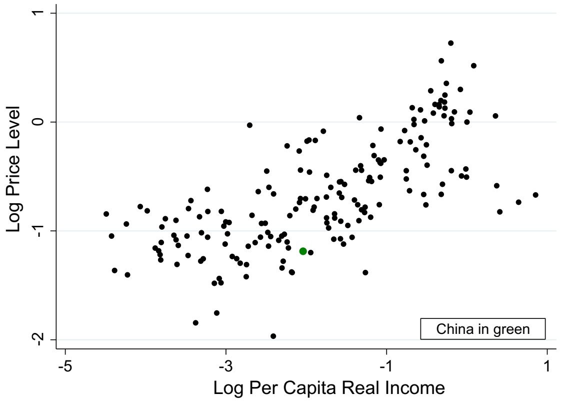
Functional form	AIC	BIC
Linear	69.050	75.391
Quadratic	23.676	33.187

Note: AIC stands for Akaike information criterion, and BIC stands for Bayesian information criterion. Both criteria suggest the functional form with the lowest score as the preferred functional form.

our previous results are summarized in Table C.6.[20] The linear functional form is the preferred functional form for some stratifications with small sample sizes. However, the quadratic functional form becomes the preferred choice when we repeat these analyses with a grouping that yields larger data sets,[21] which is the sample half. In the preferred specifications, none of the analyses indicate an undervaluation of the Chinese renminbi.

[20] Details and figures of all estimations can be provided upon request.
[21] The sample sizes for the quartile estimations are around 40.

(a) PWT 9.0 2005



(b) PWT 9.0 2011

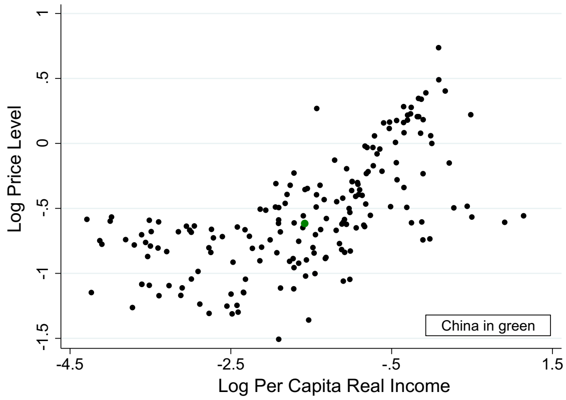


Fig. C.7. PWT 9.0 2005 and 2011 cross sections.

Note: Panel (a) shows the price-income relationship for the 2005 cross section of PWT 9.0. Panel (b) shows the same relationship for the 2011 cross section of PWT 9.0. In both panels, the price level of China is depicted with a green data point. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table C.5
Model selection criteria PWT 9.0.

Model	2005		2011	
	AIC	BIC	AIC	BIC
Linear	149.295	155.681	123.817	130.203
Quadratic	146.368	155.947	114.559	124.137

Note: AIC stands for Akaike information criterion, and BIC stands for Bayesian information criterion. Both criteria suggest the functional form with the lowest score as the preferred functional form.

6. Conclusion

In this paper, we analyze the alleged undervaluation of the Chinese renminbi against the US dollar by revisiting the PPP approach. By utilizing a new data set, ICP 2011, and following the discussion on the functional form of the Balassa-Samuelson effect, we find no evidence for the alleged undervaluation of the Chinese renminbi against the US dollar as of 2011. The existence of an undervaluation of the Chinese renminbi against the US dollar, which has been the focus of the literature so far, is only revealed if we use the log linear functional form, whose significant rejection as a preferred functional form is suggested by model selection tests. Our main results, as well as some of our robustness tests, suggest that the Chinese renminbi is neither undervalued nor overvalued whereas the other robustness tests suggest that the Chinese renminbi may be overvalued. Hence, we conclude that the PPP approach robustly shows no evidence for the alleged undervaluation of the renminbi as of 2011.

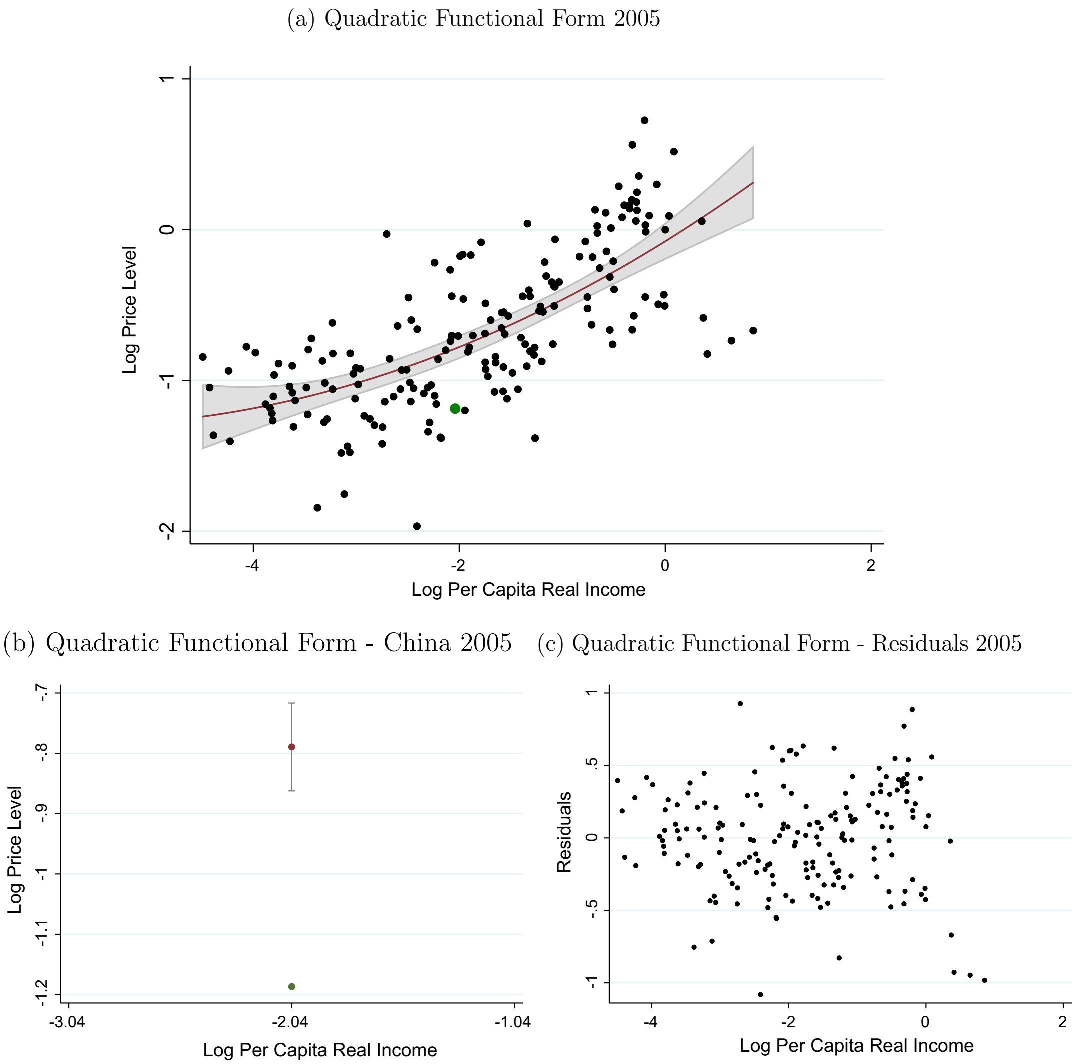


Fig. C.8. OLS estimation results PWT 9.0 2005.
Note: Panel (a) shows the estimated price levels in red, and the 95% confidence interval in gray. The observed price level of China is represented by the green data point. Panel (b) emphasizes the observed price level of China, the estimated price level of China, and the confidence interval. Panel (c) plots the residuals from the OLS estimation using the quadratic functional form against the regressor. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Acknowledgement

Almås acknowledges valuable support from Vetenskapsrådet (the Swedish Research Council), ESOP, University of Oslo, The Choice Lab, Norwegian School of Economics, and the "young research talents" program of the Norwegian Research Council. We would like to thank Gernot Doppelhofer, Robert Inklaar, and Øystein Thøgersen for helpful comments.

Appendix A. Additional sensitivity analyses

A.1. Nonparametric estimation: Using per capita real income levels

We estimate the relationship between price levels and per capita real incomes with a nonparametric estimation by using the following specification,

$$ln(PL_i) = f(ln(GDPP_i)) + \varepsilon_i \quad \text{(A.1)}$$

where $f(\cdot)$ is a smooth function, and the ε_i's are normally distributed disturbances with mean zero and standard deviation σ. The value of $f(\cdot)$ is estimated by using a kernel weighted local polynomial estimator of degree one (Yatchew, 2003).

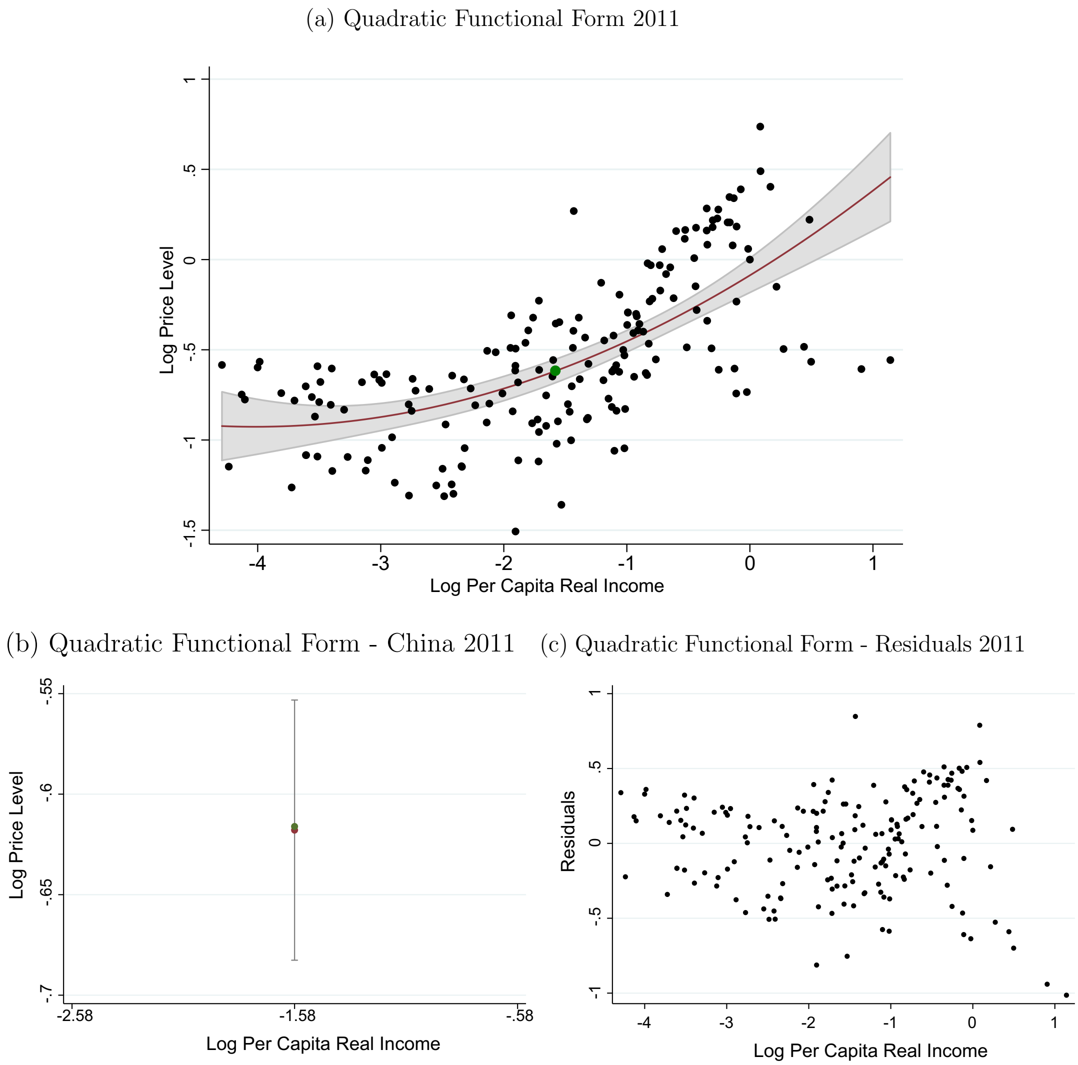


Fig. C.9. OLS estimation results PWT 9.0 2011.

Note: Panel (a) shows the estimated price levels in red, and the 95% confidence interval in gray. The observed price level of China is represented by the green data point. Panel (b) emphasizes the observed price level of China, the estimated price level of China, and the confidence interval. Panel (c) plots the residuals from the OLS estimation using the quadratic functional form against the regressor. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Epanechnikov kernel is used as the weighting function because it minimizes the mean squared error of the local polynomial estimator (Gijbels and Fan, 1996). The reported results are calculated by using the rule of thumb bandwidth.[22] However our results are robust to the use of the cross validated bandwidth, and any other reasonable bandwidth in this regard.[23]

Log of the price level of China is estimated as -0.665 with a 95% confidence interval (-0.740, -0.590). Recalling that the observed log price level of China is -0.612, a nonparametric estimation suggests that the Chinese renminbi is not undervalued against the US dollar as of 2011. Hence the result that is suggested by the nonparametric fit supports the result provided by the quadratic functional form. Fig. C.11 represents these results.

A.2. Controlling for sectoral labor mobility

In order to avoid multicollinearity, which is caused by using correlated explanatory variables per capita real income and mean years of education (see Fig. C.12), we estimate a robust OLS regression of log price level on the first principle compo-

[22] Rule of thumb bandwidth is calculated by obtaining a pilot estimate, and using statistics from this estimate to calculate the asymptotically optimal bandwidth.

[23] Cross validated bandwidth is the bandwidth that minimizes the mean squared error of the nonparametric estimation. For more information, see e.g., Gijbels and Fan (1996).

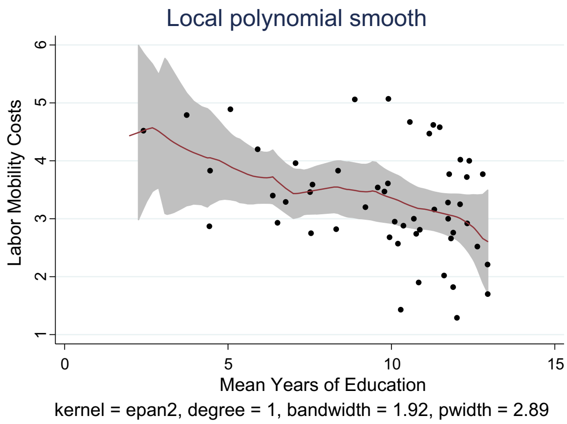


Fig. C.10. Labor mobility cost and mean years of education.
Note: The figure displays the relationship between the labor mobility costs and the mean years of education for 2011. The data is plotted for 53 countries that are common to Artuc et al. (2015) and ICP 2011.

Table C.6
Results summary.

Price level data	Controls	Functional form	Misalignment
ICP 2011		Quadratic	No misalignment
ICP 2011		Non-parametric	No misalignment
ICP 2011 (expenditure)		Quadratic	Overvalued (17%)
PWT 9.0		Quadratic	No misalignment
ICP 2011	Labor mobility	Quadratic	Overvalued (11%)
ICP 2011	Labor mobility	Non-parametric	No misalignment
ICP 2011	Net foreign assets	Quadratic	No misalignment
ICP 2011 (w/o Top oil exporters)		Quadratic	No misalignment
ICP 2011 (2nd income quartile)		Linear	No misalignment
ICP 2011 (1st income half)		Quadratic	No misalignment
ICP 2011 (2nd gini quartile)		Quadratic	Overvalued (11%)
ICP 2011 (1st gini half)		Quadratic	Overvalued (13%)
ICP 2011 (1st temperature quartile)		Quadratic	Overvalued (11%)
ICP 2011 (1st temperature half)		Quadratic	Overvalued (10%)
ICP 2011 (2nd institutional quartile)		Linear	Overvalued (10%)
ICP 2011 (1st institutional half)		Quadratic	Overvalued (15%)

Note: The table presents a summary of misalignment analyses. The first column documents the data set used. The expenditure indicates use of expenditure data instead of income data. "w/o" stands for without. Quartiles and halves show which subsamples of the indicated data set is used for each analysis, e.g. in which subsample China is. The second column shows additional control variables. The third column reports the misalignment results, and the distance of the log predicted price level to the log observed price level if the price level is statistically misaligned. The fourth column reports the functional form used in the analysis, which are the preferred functional forms for the parametric analyses.

nent of per capita real income and mean years of education[24] (see e.g., Joliffe, 2002). Fig. C.13 plots log price levels and the first principle component.

Table C.7, Figs. C.14 and C.15 summarize the results of OLS estimations. The coefficients of the principle component variables are positive and significant ($p - value < 0.001$). A linear functional form suggests that the Chinese renminbi is undervalued by 5.4% whereas a quadratic functional form suggests that it is overvalued by 11%. A log-likelihood ratio test yields a test statistic of 50.78 which has a $\chi^2(1)$ distribution indicating significant rejection of the null hypothesis that the coefficient of the quadratic term is zero ($p - value < 0.001$), and the AIC and BIC of the log quadratic model are again lower (see Table C.8).

Figs. C.14 panel (c) and C.15 panel (c) present residual plots of regressions using both functional forms. The log linear functional form suggests a nonlinear relationship between the regressor and the residuals whereas the log quadratic functional form suggests no significant relationship.

A nonparametric estimation using the first principle component of per capita real income and mean years of education as the explanatory variable estimates log of the price level for China as −0.678 with a 95% confidence interval (−0.753, −0.603). Therefore, a nonparametric estimation controlling for sectoral labor mobility suggests that the Chinese renminbi is not undervalued against the US dollar as of 2011. Fig. C.16 represents these results.

[24] The first principle component explains 89.94% of the variation in both variables.

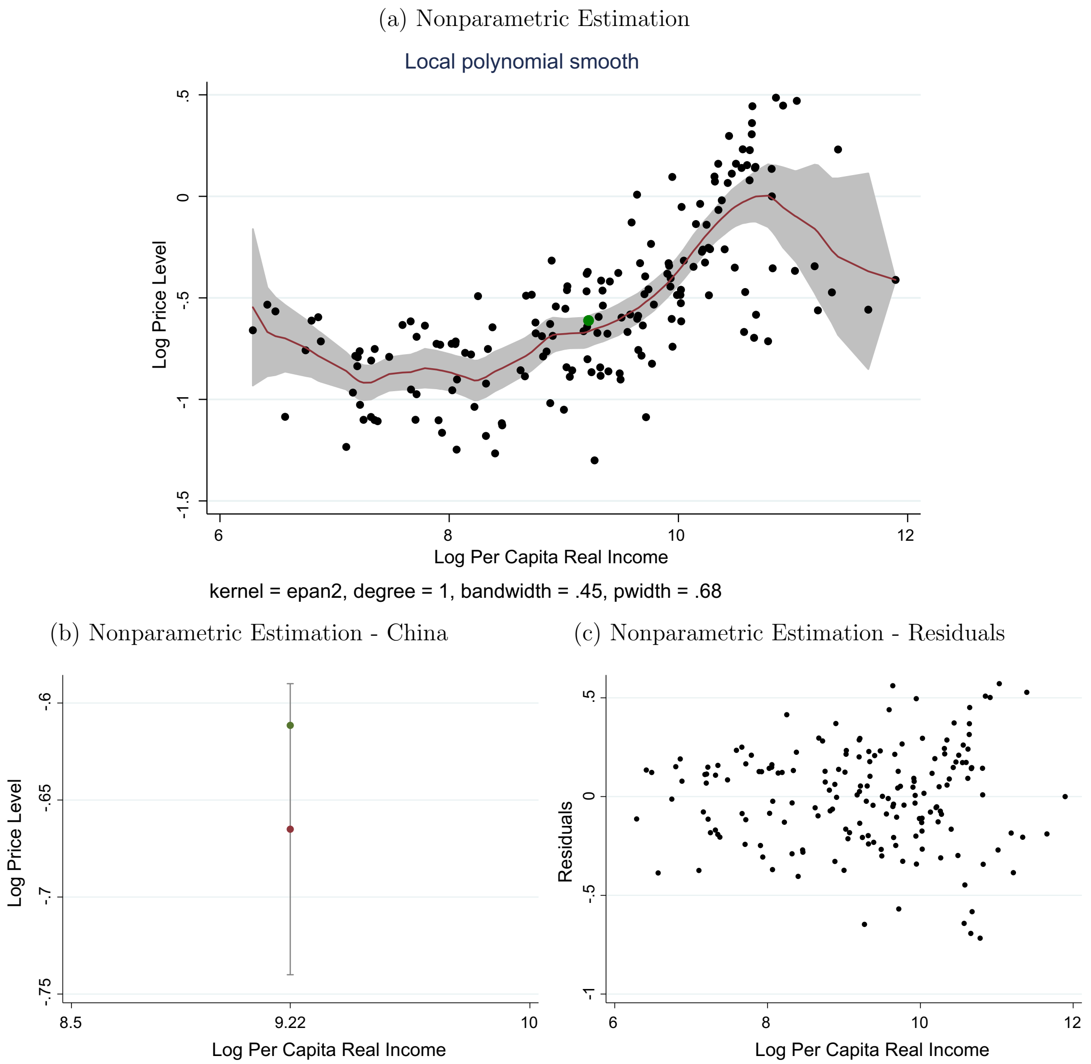


Fig. C.11. Nonparametric estimation results using income data.
Note: Panel (a) shows the estimated price levels in red, and the 95% confidence interval in gray. The observed price level of China is represented by the green data point. Panel (b) emphasizes the observed price level of China, the estimated price level of China, and the confidence interval. Panel (c) plots the residuals from the nonparametric estimation against the regressor. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

A.3. Controlling for net foreign asset positions

Table C.9 summarizes the results of the robust OLS estimations using both functional forms. nfa_i is significant in both estimations, however the log linear functional form still reveals undervaluation whereas the log quadratic functional form does not reveal any evidence of undervaluation. A log-likelihood ratio test reports the test statistic as 13.75 which has a $\chi^2_{(1)}$ distribution with a p-value indicating significant rejection of the null hypothesis that the coefficient of the quadratic term is zero ($p - value < 0.001$). Table C.10 shows that the log quadratic functional form has the lower AIC and BIC values. Therefore, again, the log quadratic functional form is the preferred functional form, and we find no evidence of renminbi undervaluation.

A.4. Exclusion of the top oil exporting economies

The top oil exporting countries are selected as the top 15 oil exporters according to The United States Energy Information Administration (The United States Energy Information Administration, 2011). The list of these countries is in Appendix B.

Table C.11 summarizes the results of the robust OLS estimations using both functional forms. All coefficients are significant. The log linear functional form suggests that the renminbi is undervalued whereas the log quadratic functional form

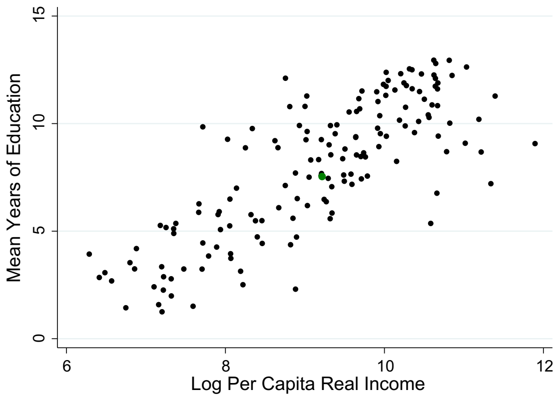


Fig. C.12. Educational attainment and per capita real income.
Note: The mean years of education is plotted on the vertical axis, and log per capita real income is plotted on the horizontal axis. China is represented by a green data point. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

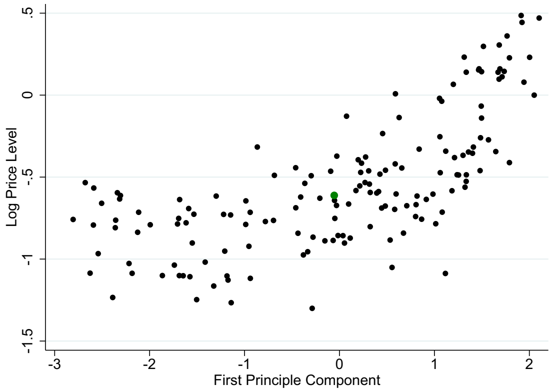


Fig. C.13. Price levels and the first principle component.
Note: Log price levels are plotted on the vertical axis, and values of the first principle component of per capita real incomes and mean years of education are plotted on the horizontal axis. China is represented by a green data point. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table C.7
OLS estimation results controlling sectoral mobility with education.

	Linear	Quadratic
PC_i	0.207***	0.258***
PC_i^2		0.090***
Constant	−0.546***	−0.708***
$ln(\hat{PL}_{China})$	−0.558	−0.722
95% CI	(−0.603, −0.513)	(−0.777, −0.667)
% misalignment	−5.4%	11%
R^2	0.480	0.625
Root MSE	0.289	0.247
Observations	156	156

***significant at 1%.
Note: PC_i stands for the first principle component value for country *i*. $\hat{PL}_{China}$ is the estimated price level of China. % misalignment is calculated as the difference between the log of the observed price level of China, which is −0.612, and the log of $\hat{PL}_{China}$ if the difference is statistically significant.

suggests that the renminbi is not undervalued. A log-likelihood ratio test reports the test statistic as 27.75 which has a $\chi^2_{(1)}$ distribution indicating significant rejection of the null hypothesis that the coefficient of the quadratic term is zero ($p - value < 0.001$). Table C.12 shows that the log quadratic functional form has the lower AIC and BIC values. Therefore our choice of the functional form and the misalignment result are robust to the exclusion of the top oil exporters.

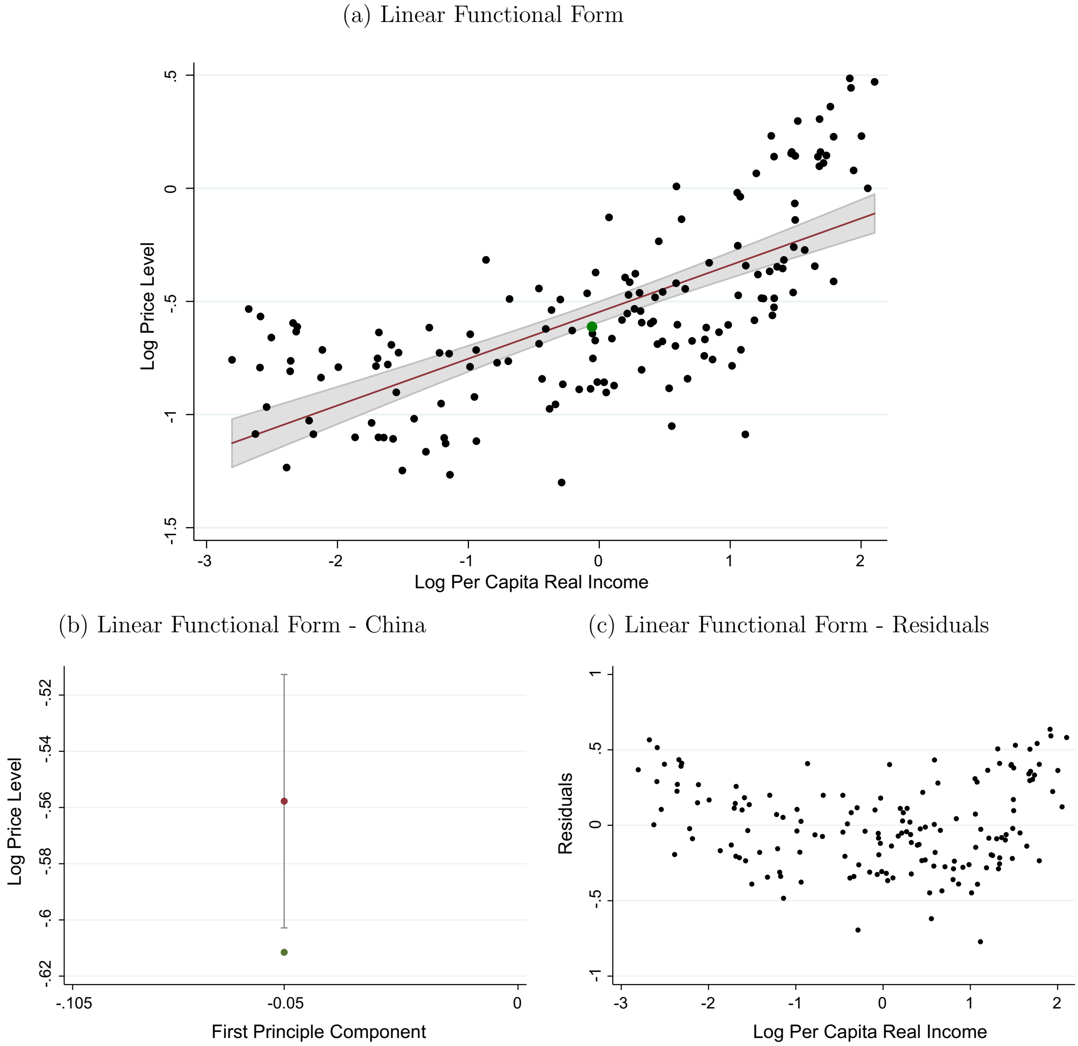


Fig. C.14. OLS estimation results controlling sectoral mobility with education – 1.
Note: Panel (a) shows the estimated price levels in red, and the 95% confidence interval in gray. The observed price level of China is represented by the green data point. Panel (b) emphasizes the observed price level of China, the estimated price level of China, and the confidence interval. Panel (c) plots the residuals from the OLS estimation using the linear functional form against the regressor. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Appendix B. Lists of countries

Countries in the main sample: Albania, Algeria, Angola, Anguilla, Antigua and Barbuda, Armenia, Aruba, Australia, Austria, Azerbaijan, the Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bermuda, Bhutan, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Cape Verde, Cayman Islands, Central African Republic, Chad, Chile, China, Colombia, Comoros, Democratic Republic of the Congo, Republic of the Congo, Costa Rica, Croatia, Curacao, Cyprus, Czech Republic, Cote d'Ivoire, Denmark, Djibouti, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Ethiopia, Fiji, Finland, France, Gabon, the Gambia, Georgia, Germany, Ghana, Greece, Grenada, Guatemala, Guinea, Guinea-Bissau, Haiti, Honduras, Hong Kong, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Republic of Korea, Kuwait, Kyrgyzstan, Lao PDR, Latvia, Lesotho, Liberia, Lithuania, Luxembourg, Macao, Macedonia, Madagascar, Malawi, Malaysia, Maldives, Mali, Malta, Mauritania, Mauritius, Mexico, Moldova, Mongolia, Montenegro, Montserrat, Morocco, Mozambique, Myanmar, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Palestinian Territory, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Romania, Russia, Rwanda, Saudi Arabia, Senegal, Serbia, Seychelles, Sierra Leone, Singapore, Sint Maarten, Slovakia, Slovenia, South Africa, Spain, Sri Lanka, St. Kitts and Nevis, St. Lucia, St. Vincent and Grenadines, Sudan, Suriname, Swaziland, Sweden, Switzerland, Sao Tome and Principe, Taiwan, Tajikistan, Tanzania,

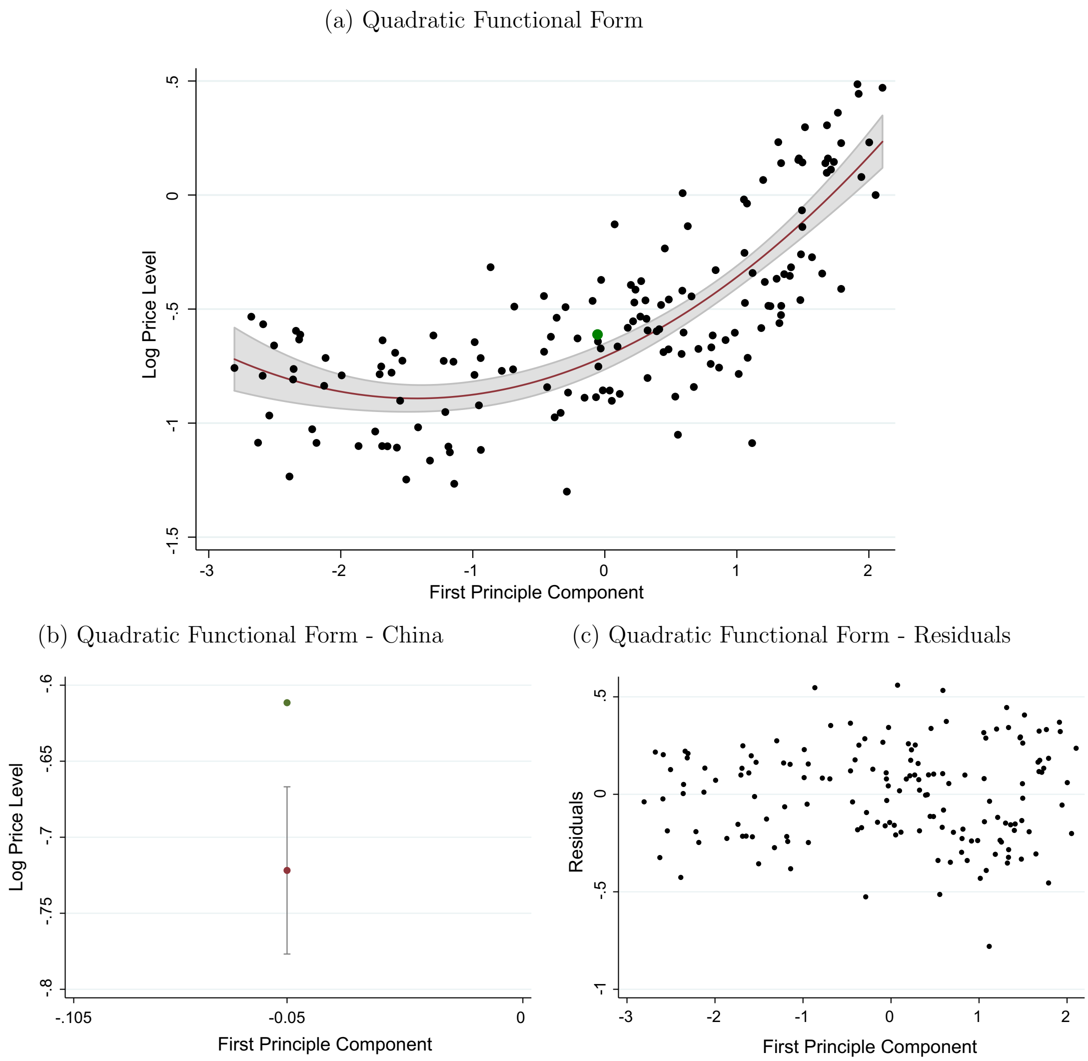


Fig. C.15. OLS estimation results controlling sectoral mobility with education – 2.
Note: Panel (a) shows the estimated price levels in red, and the 95% confidence interval in gray. The observed price level of China is represented by the green data point. Panel (b) emphasizes the observed price level of China, the estimated price level of China, and the confidence interval. Panel (c) plots the residuals from the OLS estimation using the quadratic functional form against the regressor. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table C.8
Model selection criteria controlling sectoral mobility with education.

Model	AIC	BIC
Linear	57.722	63.821
Quadratic	8.937	18.087

Note: AIC stands for Akaike information criterion, and BIC stands for Bayesian information criterion. Both criteria suggest the functional form with the lowest score as the preferred functional form.

Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Turks and Caicos Islands, Uganda, Ukraine, the United Arab Emirates, the United Kingdom, the United States, Uruguay, Venezuela, Vietnam, Virgin Islands, Yemen, Zambia.

Countries without education data: Anguilla, Aruba, the Bahamas, Bermuda, Cape Verde, Cayman Islands, Curacao, Iran, Lao PDR, Macao, Macedonia, Montserrat, Sint Maarten, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Sao Tome and Principe, Taiwan, Turks and Caicos, Virgin Islands.

Countries without gini data: Algeria, Anguilla, Antigua and Barbuda, Aruba, the Bahamas, Bahrain, Barbados, Belize, Bermuda, Brunei Darussalam, Cape Verde, Cayman Islands, Comoros, Curacao, Dominica, Egypt, Equatorial Guinea, Gabon, the

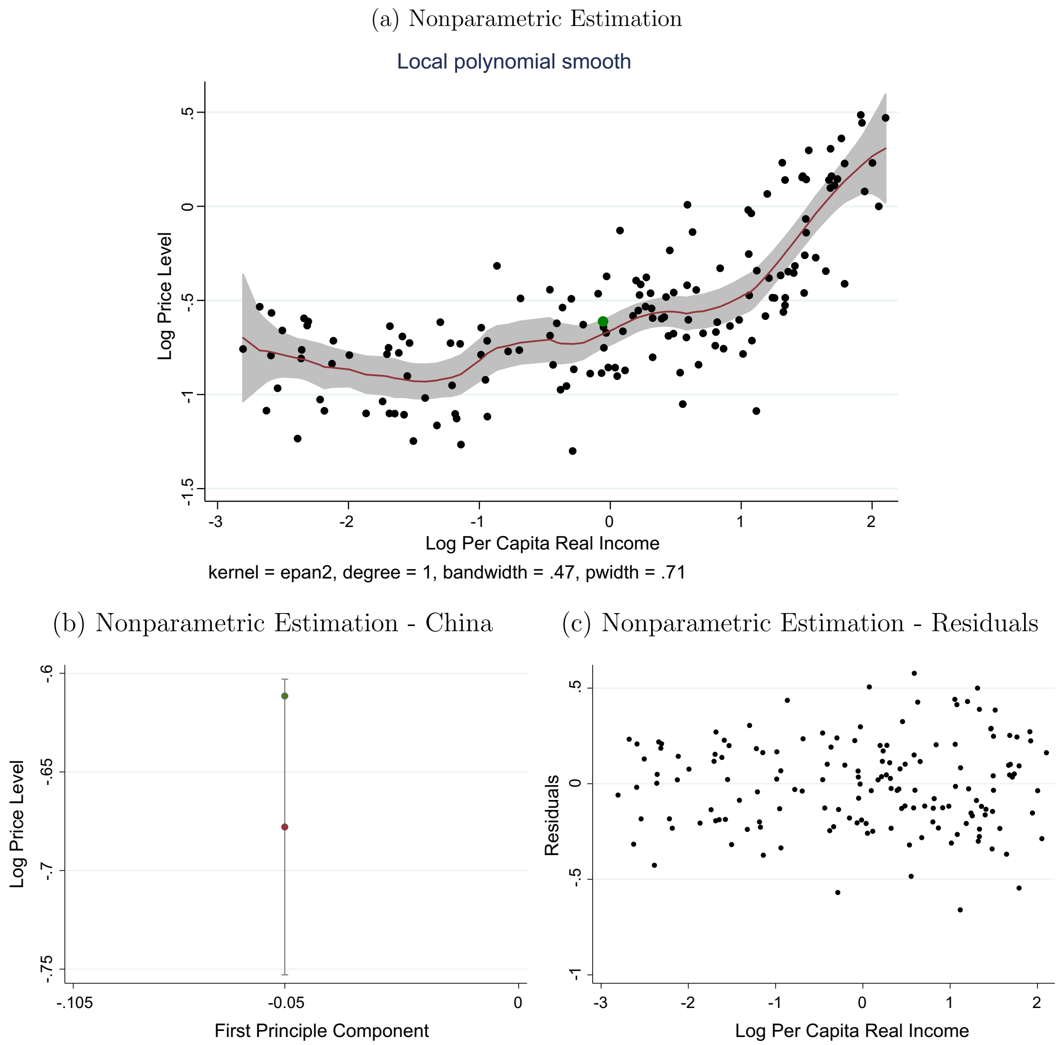


Fig. C.16. Nonparametric estimation results controlling sectoral mobility with education.
Note: Panel (a) shows the estimated price levels in red, and the 95% confidence interval in gray. The observed price level of China is represented by the green data point. Panel (b) emphasizes the observed price level of China, the estimated price level of China, and the confidence interval. Panel (c) plots the residuals from the nonparametric estimation against the regressor. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table C.9
OLS estimation results controlling NFA positions.

	Linear	Quadratic
$ln(GDPP_i)$	0.195^{***}	-0.670^{**}
$ln(GDPP_i)^2$		0.048^{**}
nfa_i	$-4.04e-16^{***}$	$-2.99e-16^{**}$
Constant	-2.340^{***}	1.462
$ln(\hat{PL}_{China})$	−0.558	−0.630
95% CI	(−0.604, −0.512)	(−0.685, −0.575)
% misalignment	−10.7%	No misalignment
R^2	0.422	0.471
Root MSE	0.288	0.276
Observations	154	154

***, ** significant at 1%, 5%, respectively.
Note: $GDPP_i$ stands for the country *i*'s per capita real income, and nfa_i stands for the country *i*'s net foreign asset position. $\hat{PL}_{China}$ is the estimated price level of China. % misalignment is calculated as the difference between the log of the observed price level of China, which is −0.612, and the log of $\hat{PL}_{China}$ if the difference is statistically significant.

Table C.10
Model selection criteria controlling NFA positions.

Model	AIC	BIC
Linear	54.332	60.406
Quadratic	42.580	51.691

Note: AIC stands for Akaike information criterion, and BIC stands for Bayesian information criterion. Both criteria suggest the functional form with the lowest score as the preferred functional form.

Table C.11
OLS estimation results excluding top oil exporters.

	Linear	Quadratic
$ln(GDPP_i)$	0.226***	−1.080**
$ln(GDPP_i)^2$		0.073***
Constant	−2.604***	3.104**
$ln(\hat{PL}_{China})$	−0.520	−0.629
95% CI	(−0.565, −0.474)	(−0.687, −0.571)
% misalignment	−9.2%	No misalignment
R^2	0.479	0.561
Root MSE	0.293	0.270
Observations	161	161

***, ** significant at 1%, 5%, respectively.
Note: $GDPP_i$ stands for the country *i*'s per capita real income. $\hat{PL}_{China}$ is the estimated price level of China. % misalignment is calculated as the difference between the log of the observed price level of China, which is −0.612, and the log of $\hat{PL}_{China}$ if the difference is statistically significant.

Table C.12
Model selection criteria excluding oil exporting economies.

Model	AIC	BIC
Linear	63.441	69.604
Quadratic	37.692	46.936

Note: AIC stands for Akaike information criterion, and BIC stands for Bayesian information criterion. Both criteria suggest the functional form with the lowest score as the preferred functional form.

Gambia, Ghana, Grenada, Hong Kong, Iraq, Jamaica, Jordan, Kenya, Republic of Korea, Kuwait, Macao, Malta, Montserrat, Myanmar, New Zealand, Oman, Palestinian Territory, Qatar, Saudi Arabia, Singapore, Sint Maarten, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Sao Tome and Principe, Taiwan, Trinidad and Tobago, Turks and Caicos Islands, the United Arab Emirates, Virgin Islands, Yemen.

Countries without temperature data: Anguilla, Antigua and Barbuda, Aruba, Bahrain, Barbados, Bermuda, Cape Verde, Cayman Islands, Curacao, Dominica, Grenada, Hong Kong, Macao, Maldives, Malta, Montserrat, Palestinian Territory, Seychelles, Singapore, Sint Maarten, St. Kitts and Nevis, St. Lucia, Sao Tome and Principe, Taiwan, Turks and Caicos Islands.

Countries without institutional data: Cape Verde, Curacao, Montserrat, Palestinian Territory, Sint Maarten, Turks and Caicos Islands.

Top oil exporting countries: Algeria, Angola, Canada, Iran, Iraq, Kazakhstan, Kuwait, Mexico, Nigeria, Norway, Qatar, Russia, Saudi Arabia, the United Arab Emirates, Venezuela.

Appendix C. Additional data sets

To obtain mean years of education, we use the education data provided by the Human Development Report 2014 (UNDP, 2014). The data set provides the average number of years of education that is received by people ages 25 and older for 156 countries.The data is collected by UNESCO Institute for Statistics and prepared by using the methodology of Barro and Lee (2013).

As indicators of income inequality, we used the 2011 GINI indices as reported by the World Bank.[25] For the countries that do not have a 2011 GINI estimate, we use the closest GINI estimate within 5 years of 2011. In total, we have GINI indices for 126 countries.

We obtain the data for average country-wise temperatures from the World Bank's Climate Change Knowledge Portal,[26] which reports mean temperatures for 151 countries in our sample from 1961 to 1999.

Our institutional indicators are obtained from the Worldwide Governance Indicators database (see Kaufmann et al., 2010). We use 2011 estimates of five governance indicators as provided by the data set for 170 countries. These indicators

25 http://databank.worldbank.org/data/reports.aspx?source=2&series=SI.POV.GINI&country=.
26 http://data.worldbank.org/data-catalog/cckp_historical_data.

are voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, control of corruption.

PWT 9.0 is explained in Section 5.1.2.

References

Artuc, E., Lederman, D., Porto, G., 2015. A mapping of labor mobility costs in the developing world. J. Int. Econ. 95 (1), 28–41.

Asian Development Bank, 2014. Purchasing power parities and real expenditures. Mandaluyong City, Philippines.

Balassa, B., 1964. The purchasing-power parity doctrine: a reappraisal. J. Polit. Econ. 72 (6), 584–596.

Barro, R.J., Lee, J.W., 2013. A new data set of educational attainment in the world, 1950–2010. J. Dev. Econ. 104, 184–198.

Bénassy-Quéré, A., Duran-Vigneron, P., Lahrèche-Révil, A., Mignon, V., 2004. Burden sharing and exchange rate misalignments within the group of twenty. CEPII Working Paper (2004–13).

Cheung, Y.W., Chinn, M., Fujii, E., 2007. The overvaluation of renminbi undervaluation. J. Int. Money Finan. 26 (5), 762–785.

Cheung, Y.W., Chinn, M., Nong, X., 2016. Estimating currency misalignment using the penn effect: it's not as simple as it looks. NBER Working Paper Series (22539).

Cline, W.R., Williamson, J., 2008. Estimates of the equilibrium exchange rate of the renminbi: Is there a consensus and if not, why not? In: Debating China's Exchange Rate Policy. Peterson Institute for International Economics, Washington, DC, pp. 131–154.

Cline, W.R., Williamson, J., 2010. Notes on equilibrium exchange rates: January 2010. Peterson Inst. Int. Econ. Policy Brief (PB-123).

Coudert, V., Couharde, C., 2009. Currency misalignments and exchange rate regimes in emerging and developing countries. Rev. Int. Econ. 17 (1), 121–136.

Cui, Y., 2013. How is the RMB exchange rate misaligned? A recent application of behavioral equilibrium exchange rate (BEER) to China. J. East Asian Econ. Integr. 17 (3), 281–310.

Deaton, A., 1997. The Analysis of Household Surveys: A Microeconometric Approach to Development Policy. World Bank Publications, Washington, DC.

Deaton, A., Aten, B., 2014. Trying to understand the PPPs in ICP 2011: why are the results so different? NBER Working Paper Series (20244).

Deaton, A., Heston, A., 2010. Understanding PPPs and PPP-based national accounts. Am. Econ. J. Macroecon. 2 (4), 1–35.

Feenstra, R.C., Inklaar, R., Timmer, M.P., 2015a. The next generation of the penn world table. Am. Econ. Rev. 105 (10), 3150–3182.

Feenstra, R.C., Inklaar, R., Timmer, M.P., 2015b. What is new in PWT 8.1? <http://www.rug.nl/ggdc/docs/what_is_new_in_pwt_81.pdf>.

Feenstra, R.C., Ma, H., Neary, P.J., Prasada Rao, D.S., 2013. Who shrunk China? Puzzles in the measurement of real GDP. Econ. J. 123 (573), 1100–1129.

Frankel, J., 2006. On the yuan: the choice between adjustment under a fixed exchange rate and adjustment under a flexible rate. CESifo Econ. Stud. 52 (2), 246–275.

Gijbels, I., Fan, J., 1996. Local Polynomial Modelling and Its Applications. Chapman and Hall, London.

Greene, W.H., 2012. Econometric Analysis. Pearson, New Jersey.

Hassan, F., 2016. The price of development: the Penn-Balassa-Samuelson effect revisited. J. Int. Econ. 102, 291–309.

Hill, R.J., Syed, I., 2010. Improving international comparisons of real output: the ICP 2005 benchmark and its implications for China. The University of South Wales Discussion Papers (2010–25).

IMF, 2011. People's Republic of China: 2011 Article IV Consultation. Tech. Rep. 11/192, International Monetary Fund, Washington, DC.

Inklaar, R., Rao, D.P., 2017. Cross-country income levels over time: did the developing world suddenly become much richer? Am. Econ. J. Macroecon. 9 (1), 265–290.

Joliffe, I.T., 2002. Principal Component Analysis. Springer, New York.

Kaufmann, D., Kraay, A., Mastruzzi, M., 2010. The worldwide governance indicators: a summary of methodology, data and analytical issues. World Bank Policy Research Working Paper (5430).

Kessler, M., Subramanian, A., 2014. Is the Renminbi Still Undervalued? Not According to New PPP Estimates. RealTime Economic Issues Watch, Peterson Institute for International Economics.

Korhonen, I., Juurikkala, T., 2009. Equilibrium exchange rates in oil-exporting countries. J. Econ. Financ. 33 (1), 71–79.

Lee, J., Milesi-Ferretti, G.M., Ostry, J., Prati, A., Ricci, L.A., 2008. Exchange rate assessments: CGER methodologies. IMF Occas. Pap. (261), 1–22

Lee, J.J., 2006. Persistent wage differential and its implications on the Balassa-Samuelson hypothesis. Appl. Econ. Lett. 12 (10), 643–648.

McCarthy, P., 2013. Extrapolating PPPs and comparing ICP benchmark results. In: Measuring the Real Size of the World Economy: The Framework, Methodology, and Results of the International Comparison Program – ICP. The World Bank, Washington, DC, pp. 473–506.

Meyer, B.D., Sullivan, J.X., 2011. Viewpoint: further results on measuring the well-being of the poor using income and consumption. Can. J. Econ. 44 (1), 52–87.

Morrison, W.M., Labonte, M., 2013. China's currency policy: an analysis of the economic issues. Tech. Rep. 1, Congressional Research Service.

Rodrik, D., 2008. The real exchange rate and economic growth. Brookings Pap. Econ. Act. (Fall), 365–412.

Rogoff, K., 1996. The purchasing power parity puzzle. J. Econ. Lit. 34 (2), 647–668.

Samuelson, P.A., 1964. Theoretical notes on trade problems. Rev. Econ. Stat. 46 (2), 145–154.

Samuelson, P.A., 1994. Facets of Balassa-Samuelson thirty years later. Rev. Int. Econ. 2 (3), 201–226.

Schmillen, A., 2013. Are wages equal across sectors of production? Econ. Transit. 21 (4), 655–682.

Strauss, J., Ferris, M.E., 1996. The role of nontraded and traded wages in the productivity differential model. South Econ. J. 63 (2), 327.

Subramanian, A., 2010. New PPP-based estimates of renminbi undervaluation and policy implications. Peterson Inst. Int. Econ. Policy Brief (PB10-8).

The United States Energy Information Administration, 2011. Exports of Crude Oil Including Lease Condensate. <http://www.eia.gov/beta/international/>.

UNDP, 2014. Human Development Report 2014 – Sustaining human progress: reducing vulnerability and building resilience. United Nations Dev. Program.

U.S. Department of the Treasury Office of International Affairs, 2014. Report to congress on international economic and exchange rate policies. Tech. rep.

U.S. Department of the Treasury Office of International Affairs, 2015. Report to congress on international economic and exchange rate policies. Tech. rep.

World Bank, 2014. Purchasing power parities and real expenditures of world economies: summary of results and findings of the 2011 International Comparison Program. Tech. rep., The World Bank, Washington, DC.

Yatchew, A., 2003. Semiparametric Regression for the Applied Econometrician. Cambridge University Press, Cambridge.

Zhang, Z., Chen, L., 2014. A new assessment of the Chinese RMB exchange rate. China Econ. Rev. 30, 113–122.