Triangular PPP

– Theoretical perspectives and empirical evidence

Peijie Wang[a] and Fangya Xu[b]

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Abstract: We propose a triangular PPP analytical framework in this paper, which is theoretically justified and empirically validated. The peg of the RMB to the US dollar causes a triangular PPP effect that the dollar euro exchange rate is not a function of the relative prices in the US and Euroland; instead, it becomes a function of the relative prices in PRC and Euroland. The results are supportive of triangular PPP for the dollar euro exchange rate in a three-economy world of the US, Euroland and PRC.

Key words: exchange rate; PPP; triangular PPP

JEL No: F3

[a] University of Plymouth; email: Peijie.Wang@plymouth.ac.uk
[b] University of Plymouth; email: Fangya.Xu@plymouth.ac.uk

1. Introduction

Foreign exchange and an orderly foreign exchange market are crucial to international economic co-operations. It facilitates international trade and transactions. Time and again, exchange rates and exchange rate determination are scrutinized to identify with such issues as whether import and export are carried out under fair terms of trade.

Without resorting to complex models, there are several constraints imposed upon bilateral exchange rates. They are purchasing power parity (PPP), covered interest rate parity (CIRP), uncovered interest rate parity (UIRP), and international Fisher effect (IFE). These parities must hold to prevent arbitrage profits from materializing, after taking various factors into account, such as transportation. Another is non-arbitrage constraint in a triangular transaction process involving three currencies.

PPP, CIRP, UIRP and IFE should hold under the floating exchange rate arrangement without capital controls. These parities need not hold under fixed exchange rate regimes with capital controls. Nonetheless, non-arbitrage in a triangular circle of transactions must be upheld, notwithstanding fixed exchange rate arrangements and capital controls.

We propose a triangular PPP hypothesis in this paper. A triangle, or a triangular circle of transactions, is formed in a triangular PPP analytical framework. It consists of two floating currencies, and a third currency pegged to one of the floating currencies. PPP applies, or seemingly applies to the floating currencies. The triangular circle of transactions is bounded by non-arbitrage with the pegged currency. Non-arbitrage is upheld, whether PPP holds or not.

Our study is motivated by a dazzling foreign exchange market witnessed in recent years, arising from the peg of a large currency, i.e., the RMB, to the US dollar. The relevant monetary authorities, as well as researchers, still attempt to apply, in practice and in theory, those traditional, standard models of exchange rate determination that can only work for small economies regardless.

A triangular PPP effect comes into force when the exchange rate between the two floating currencies is not a function of the relative price levels in the two countries. That is, adopting consumer price indexes (CPIs) for price levels, the exchange rate between the two floating currencies is not a function of ratios between the CPIs of the two economies. Amazingly, it becomes a function of ratios between the CPIs of the pegging currency's economy and the economy of the floating currency that is not being pegged. This gives rise to triangular PPP. We examine this triangular PPP effect empirically after presenting the analytical framework.

The rest of the paper progresses as follows. The next section provides a brief review of the pertinent emerging literature. The triangular PPP framework is outlined in Section 3. Then, Section 4 presents test specifications and Section 5 implements the triangular PPP analysis and reports the evidence. Finally, Section 6 summarizes this study.

2. A brief review of the literature

2.1. Recent developments in RMB studies

Remarking on pegs of a large currency to another large currency, Wang (2013) reasons "A new issue has then emerged: the anchor, whether it is an anchor in a harbor or a large vessel, has itself been towed away, because the anchoring ship is simply too large. Consequently, the positions of all other boats have changed to varied degrees. Put it straightforwardly, the exchange rates between various pairs of currencies may be affected by such kind of anchoring". Fratzscher and Mehl (2011) have also noted the dominant role of the economy as well as the currency of China in a tri-polar global currency system centered around the three currencies of the US dollar, the euro and the RMB. There are differences in these studies with regard to the RMB's influence. In Wang's (2013) work, the influence of the RMB is over the major world currencies including the euro; whereas in Fratzscher and Mehl's (2011) tri-polar global currency system, it is about the influence of the RMB in the region of Asia, alongside, or more exactly, following, the US dollar and the euro.

The literature on pegs can be referred to Meissner and Oomes (2008) and Reinhart and Rogoff (2004). Meissner and Oomes (2008) review and summarize pegs and why countries peg their currencies to other currencies. Reinhart and Rogoff (2004) have examined extensively de facto peg regimes with natural classifications, detailing pegged floats and floating pegs. Since many countries apply de facto pegs while claiming to have floated their currencies, and some other countries prefer de facto pegs to de jure pegs, we adopt loosely defined pegs here as suggested in Wang (2013): "A peg is when the exchange rate moves consistently within a narrow band of fluctuations against a particular currency. The currency that pegs may appreciate (depreciate) all the way for a considerably long period. While the band remains narrow, the mean of the band changes and it changes consistently in one direction".

2.2. Review of the PPP literature

To conform to the weak form PPP and strong form PPP test specifications that will be presented in Section 4, we focus on tests of stationarity of real exchange rates and co-movements between the nominal exchange rate and relative price levels. To begin with, we would like to point out the regime effect on the validity or deviations from PPP and adjustment mechanisms under different exchange rate regimes. The general consensus is that the results and findings for the validity of PPP are mixed. PPP holds for countries with flexible exchange rate regimes to a greater extent than for countries with fixed exchange rate regimes. Since most developed countries adopt flexible exchange rate regimes and many developing countries adopt fixed exchange rate regimes, it is inferred that PPP is more likely to hold between developed countries, and PPP is relatively less likely to hold between developing countries or between a developing country and a developed country. This is evident in Cashin and McDermott (2006), where the majority of countries experience finite deviations of real exchange rates from parity. The speed of parity reversion is found to be much faster for developed countries than for developing countries; and fairly plainly, to be considerably faster for countries with flexible

nominal exchange rate regimes than countries with fixed nominal exchange rate regimes. Sarno and Valente (2006) summarize regime effects and mechanisms meticulously. They suggest that during fixed exchange rate regimes, relative prices adjust to restore long-run equilibrium when economies experience deviations from PPP, while exchange rates bear most of the burden of adjustment during flexible exchange rate regimes. Given the convention of small open economy thinking and empirical cases of small open economies in most studies, it is the price of the small open economy that adjusts to restore equilibrium from PPP deviations. In the present study, prices may not be responsive in fixed exchange rate regimes however, as the country adopting a fixed/pegged exchange rate regime is a large economy.

Early studies that resort to stationarity tests of real exchange rates have reported the rejection of PPP in the floating period. Examples can be found in Adler and Lehmann (1983), Darby (1983), Hakkio (1984), Meese and Rogoff (1988) and Baillie and McMahon (1989). Whereas newer studies carried out in the last decades either report mixed results or are in favor of PPP. The former includes Choi (2004), Nusair (2004), Narayan (2005) and Murray and Papell (2005a, b). Scrutinizing the asymmetric adjustment process toward parity for a sample of nine Asian economies during the post-Bretton Woods floating exchange rate era, Holmes and Wang (2006) find that long-run purchasing power parity is most likely to hold with respect to positive deviations only in most cases in the sample. Using Eurostat data, Imbs *et al.* (2005) observe that the estimated persistence of real exchange rates falls dramatically when heterogeneity is taken into account. Its half-life may fall to as low as eleven months. Lean and Smyth (2007) also find evidence of PPP for two thirds in their sample of 15 Asian countries. Allowing for regime changes, Assaf (2008) claims to have found new evidence on the stationarity of bilateral real exchange rates. The study of Kanas (2006) alleges that there are periods over which the real exchange rate is stationary and PPP holds and periods over which the real exchange rate is non-stationary and PPP does not hold for most countries. Further it is found that the probability of the real exchange rate being stationary is less than 50% for most countries.

The implication of long-run PPP is generally interpreted as the co-movement of the nominal exchange rate and the relative price levels between the two countries. Adopting the Johansen procedure, MacDonald (1993) tests for a long-run relationship between exchange rates and relative prices for five bilateral US dollar exchange rates against the Canadian dollar, the French franc, the German mark, the Japanese yen and the British pound, using post Bretton Woods data from January 1974 to June 1990. He also tests for the proportionality of the exchange rate with respect to relative prices, which is equivalent to testing stationarity in real exchange rates. He reports that the co-movement thesis receives robust support from the data, whilst the proportionality thesis is given practically no support. Similar research is also followed by Cheung and Lai (1993), Cochrane and DeFina (1995), Kugler and Lenz (1993), Pippenger (1993), Jacobson and Nessen (2004), and Paya and Peel (2007), among others. Overall, their evidence is supportive of the co-movement between the exchange rate and the respective relative prices; but is less in favor of proportionality in the co-movement.

The above review demonstrates mixed results for PPP. Amongst the mixed results, PPP holds for countries with flexible exchange rate regimes to a greater extent than for countries with fixed exchange rate regimes. Likewise, PPP is more likely to hold between developed countries, and PPP is relatively less likely to hold between developing countries or between a developing country and a developed country. Our analytical framework for a large currency with a fixed/pegged exchange rate regime points to the prospect of the opposite mixed results, contributing to the literature.

3. The triangular PPP framework and implications

3.1. The analytical framework

Let us employ the RMB, the US dollar and the euro to make a triangle with the following bounding relationship:

$$e_{¥/€,t} = e_{\$/€,t} \cdot e_{¥/\$,t} \quad (1)$$

where $e_{¥/€,t}$ is the exchange rate between the RMB and the euro, defined as number of Yuan (RMB units) per euro, $e_{\$/€,t}$ is defined as units of dollars per euro, and $e_{¥/\$,t}$ is defined as number of Yuan per dollar. Taking a logarithmic operation for equation (1) yields:

$$Ln(e_{¥/€,t}) = Ln(e_{\$/€,t}) + Ln(e_{¥/\$,t}) \quad (2)$$

We now consider PPP for the three currencies. Since the RMB is pegged to the US dollar, the exchange rate between them is not expected to follow PPP. i.e., the following relationship is not expected to be upheld:

$$Ln(e_{¥/\$,t}) = c_1 + Ln(CPI_{¥,t}) - Ln(CPI_{\$,t}) \quad (3)$$

where $CPI_{¥,t}$ is the CPI of People's Republic of China (PRC) and $CPI_{\$,t}$ is the CPI of the US at time *t*, and c_1 is an intercept[1]. Whereas the dollar euro exchange rate can be expected to abide by PPP:

$$Ln(e_{\$/€,t}) = c_2 + Ln(CPI_{\$,t}) - Ln(CPI_{€,t}) \quad (4)$$

where $CPI_{€,t}$ is the CPI of Euroland at time *t*, and c_2 is an intercept. However, equation (4) is subject to empirical verification. The RMB euro exchange rate is "freely" floating, due to the fact that it is the product of the dollar euro exchange rate and the RMB dollar exchange rate, and the former is freely floating. So, it can be expected that:

$$Ln(e_{¥/€,t}) = c_3 + Ln(CPI_{¥,t}) - Ln(CPI_{€,t}) \quad (5)$$

where c_3 is an intercept. Equation (5) is also subject to empirical verification. If PPP holds empirically for the RMB euro exchange rate, then equation (5) is valid. According to equation (2) and equation (5):

$$Ln(e_{\$/€,t}) = c_4 + Ln(CPI_{¥,t}) - Ln(CPI_{€,t}) - Ln(e_{¥/\$,t}) \quad (6)$$

where c_4 is an intercept. Mathematically, bringing equation (3) back into equation (6) reproduces equation (4). However, this mathematical operation is valid if and only if the relationship in equation (3) is upheld. Given a pegged RMB that steadily appreciated against the US dollar,

[1] If we made all CPIs 100 in year 0, then c_1 is equal to $Ln(e_{¥/\$,0})$.

$Ln(e_{¥/\$,t})$ is virtually a linear trend, with fluctuations much narrower than those associated with flexible exchange rates. So, equation (6) can be presented as:

$$Ln(e_{\$/€,t}) = c_4' + \delta t + Ln(CPI_{¥,t}) - Ln(CPI_{€,t}) + \nu_t \quad (7)$$

where δ is coefficient, and ν_t is a random variable with a zero mean, reflecting confined fluctuations in the RMB dollar exchange rate that is much narrower than those associated with flexible exchange rates. Given a steadily appreciating RMB vis-à-vis the US dollar, $E\{Ln(e_{¥/\$,t})\} < 0$. So $\delta > 0$.

3.2. Discussions and implications

With $e_{¥/\$,t}$ in equation (6) and $e_{¥/\$,t}$ being not determined by equation (3), the US price level is out of the equation for dollar euro exchange rate determination. This is reinforced by equation (7) where $Ln(e_{¥/\$,t})$ is represented more distinctly by $\delta t + \nu_t$. Moreover, equation (7) indicates that the euro would steadily appreciate vis-à-vis the US dollar at a time the general economic environment does not change. One of the unchanged general economic environment cases is that the relative price levels remain the same in equation (6) or equation (7). This is disquieting. It was exactly what had happened before the financial crisis. The culprit was δt, or the steady appreciation of the RMB against the US dollar, which is made obvious by the relationship in equation (7).

The above relationship, arising from the peg of the RMB to the US dollar, crucially justifies why and how the dollar euro exchange rate can be a function of the price level in PRC, or the relative prices in PRC and Euroland. While the US price level is out of the equation, there is a role for the PRC price level in the equation. The peg of a large currency RMB to the US dollar effectively creates a union of currencies in which the RMB constitutes a large share. This gives rise to the role of PRC fundamentals in influencing the relative value of the US dollar vis-à-vis other currencies on the one hand; it distorts the exchange rates of the US dollar vis-à-vis other

currencies on the other hand. The validity of either equation (6) (equation (7)) or equation (4) is then subject to empirical examination, depending on the extent of influence and distortion exerted by the peg of the RMB to the US dollar.

A joint examination of equation (4) and equation (6) provides us with a means to assessing the RMB effect. Assume a world consisting of three economies only: the US, Euroland and PRC. Under such circumstances, equation (4) and equation (6) would be validated or invalidated by the economic variables in these three economies only. If the RMB were a small currency, equation (6) would have been invalid. The assumptions on small open economics are that they are influenced by the world but they do not influence the world. Thus, the inflation in PRC would have no impact on the dollar euro exchange rate. A valid equation (6), which invalidates equation (4) in the meantime, indicates a fully exerted RMB effect. Equation (4) should have held in a perfect world of these three economies only, if and when under no influence of PRC economic variables. A more valid equation (6) and less valid equation (4) indicate a stronger RMB effect, and vice versa.

The validity of equation (6) depends on the validity of equation (5), i.e., PPP holds for the pegging currency and the floating currency that is not being pegged: the RMB and the euro. We call a valid equation (6) and an invalid equation (4) triangular PPP: the exchange rate between the two floating currencies is not the inflation differentials between themselves but the inflation differentials involving the third currency in a triangular circle. Triangular PPP holds for the two floating currencies under this circumstance, and the exchange rate between them becomes a function of inflation differentials between the pegging currency's economy and the economy of the floating currency that is not being pegged. As equation (7) is a simplified representation of equation (6), we call it simple triangular PPP, and then call equation (6) standard triangular PPP.

Equation (5) can also help solve the so called puzzle of "internal depreciation and external appreciation of the RMB". The puzzle refers to the phenomenon of the gradual appreciation of the RMB vis-à-vis the US dollar, at a time when inflation in PRC was considered high and higher

than that in the US. Relative to the euro, no such external appreciation had existed, which will be shown in Section 5.

4. Test specifications

PPP is tested for the weak and strong form. Weak form tests are to examine whether the variables in equation (4), equation (5) and equation (6) are cointegrated respectively. In this regard, the validity of equation (6) depends on the validity of equation (5) to a lesser degree, which will be demonstrated in the following analysis of specifications.

For a weak form of PPP for the dollar euro exchange rate, it is to test whether a linear combination of $Ln(e_{\$/€,t})$, $Ln(CPI_{\$,t})$ and $Ln(CPI_{€,t})$ is stationary or not. It is expressed as follows:

$$Ln(e_{\$/€,t}) + \alpha_1 Ln(CPI_{\$,t}) + \beta_1 Ln(CPI_{€,t}) = \theta_{\$€,t} \quad (4')$$

where α_1 and β_1 are coefficients, and $\theta_{\$€,t}$ is the resultant combination. Weak form PPP holds for the dollar euro exchange rate if a linear combination of these three variables, or $\theta_{\$€,t}$, is stationary. Similarly for the RMB euro exchange rate, it is to test whether the following combination, or $\theta_{¥€,t}$, is stationary for the validity of weak form PPP:

$$Ln(e_{¥/€,t}) + \alpha_2 Ln(CPI_{¥,t}) + \beta_2 Ln(CPI_{€,t}) = \theta_{¥€,t} \quad (5')$$

where α_2 and β_2 are coefficients. Weak form triangular PPP holds for the dollar euro exchange if the following linear combination, or $\theta_{¥€\$,t}$, is stationary:

$$Ln(e_{\$/€,t}) + \alpha_3 Ln(CPI_{¥,t}) + \beta_3 Ln(CPI_{€,t}) + \gamma_3 Ln(e_{¥/\$,t}) = \theta_{¥€\$,t} \quad (6')$$

where α_3, β_3 and γ_3 are coefficients. Similar to the derivation of equation (7) from equation (6) and for cointegration tests, $Ln(e_{¥/\$,t})$ may be taken out from equation (6'), allowing a linear deterministic trend in test specifications:

$$Ln(e_{\$/€,t}) + \alpha_3' Ln(CPI_{¥,t}) + \beta_3' Ln(CPI_{€,t}) = \theta_{¥€\$,t}' \quad (7')$$

Strong form tests impose proportionate restrictions on the variables in the above three equations: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_3' = -1, \beta_1 = \beta_2 = \beta_3 = \beta_3' = 1, \gamma_3 = 1$. So strong form tests assess whether the following residuals are stationary:

$$Ln(e_{\$/€,t}) - Ln(CPI_{\$,t}) + Ln(CPI_{€,t}) = c_2 + \varepsilon_{\$€,t} \quad (4")$$

$$Ln(e_{¥/€,t}) - Ln(CPI_{¥,t}) + Ln(CPI_{€,t}) = c_3 + \varepsilon_{¥€,t} \quad (5")$$

$$Ln(e_{\$/€,t}) - Ln(CPI_{¥,t}) + Ln(CPI_{€,t}) + Ln(e_{¥/\$,t}) = c_4 + \varepsilon_{¥€\$,t} \quad (6")$$

$$Ln(e_{\$/€,t}) - Ln(CPI_{¥,t}) + Ln(CPI_{€,t}) = c_4' + \varepsilon_{¥€\$,t}' \quad (7")$$

Given equation (2), equation (6") is exactly the same as equation (5"), so $\varepsilon_{¥€\$,t} \equiv \varepsilon_{¥€,t}$ and $c_4 = c_3$. This is exactly what has been said earlier in the previous section that the validity of equation (6) depends on the validity of equation (5), which refers to strong form PPP. However, when weak form PPP is introduced, varied results are allowed empirically for equation (5') and equation (6').

5. Evidence

Our data sets of exchange rates and CPIs start from July 2005, when the People's Bank of China announced/ adopted managed floating, and stop by June 2013. The data sets are at the monthly frequency, the highest frequency for inflation data. There are two major and authoritative souses of inflation statistics for PRC. One is National Bureau of Statistics of China (NBSC) and the other Organization for Economic Co-operation and Development (OECD). The inflation rate produced by NBSC is lower, sometimes considerably lower than that produced by OECD. It is difficult for us to take sides. So, we make three measures, or modified indexes for PRC inflation. The first is an average of the two indexes by NBSC and OECD. The second is the index by NBSC alone. The third takes the improvement in PRC's economic statistics compilation into consideration. The scale of fallacy or erroneousness of statistical data has been reduced gradually, and the accuracy in statistical data has been raised too, with time going by. Thus, OECD's index

is adopted for the period before the financial crisis, and then NBSC's index is employed for the post crisis period.

The three pairs of exchange rates and the corresponding CPI ratios are plotted in Figure 1[2], adopting the first measure for PRC inflation. The top panel exhibits the RMB euro exchange rate and the CPI ratio between PRC and Euroland; the middle panel is for the dollar euro exchange rate and the CPI ratio between the US and Euroland; and the bottom panel demonstrates triangular PPP for the dollar euro exchange rate. Figure 2 and Figure 3 replicate these graphs, using the second measure and third measure for PRC inflation respectively. Clearly, PPP does not hold for the dollar euro exchange rate and price movements in the US and Euroland, observing the middle panel of Figure 1. While the US price level was steadily slightly higher than that in Euroland, the exchange rate fluctuated spectacularly. The euro appreciated to a much greater extent as could be warranted by inflation differentials prior to the financial crisis; and swung volatilely, keeping no pace with inflation movements in the whole post-crisis period.

{Figure 1}

{Figure 2}

{Figure 3}

In contrast, there were synchronised co-movements between the RMB euro exchange rate and the CPI ratio between PRC and Euroland, indicated by the top panel of Figure 1, Figure 2 and Figure 3 with three different CPI measures for PRC. Figure 3 exhibits the best fit graph, adopting the third CPI measure. More interestingly, the dollar euro exchange rate seemed to track the CPI ratio between PRC and Euroland instead, being augmented by the RMB dollar exchange rate. The dollar euro exchange rate tracked the CPI ratio between PRC and Euroland

[2] The position of the exchange rate is shifted, according to Footnote 1.

particularly well in the bottom panel of Figure 3. Moreover, all of Figure 1, Figure 2 and Figure 3 show that the sum of the three curves almost makes a stable line, indicating stationarity and upholding triangular PPP. Changes in the dollar euro exchange rate can be well matched by the joint movements in the CPI ratio between PRC and Euroland and the RMB dollar exchange rate, except for the period between October 2008 and June 2010 when the RMB dollar exchange rate was fixed for nearly two years. These graphical observations demonstrate mixed results for PPP contrary to the existing literature. PPP does not hold for economies with flexible exchange rate regimes, but seems to hold for a country with pegged exchange rate regimes, albeit in relation to an economy whose currency is not being pegged. The observations point to triangular PPP for the dollar euro exchange rate.

{Table 1}

{Table 2}

Our statistical estimation results also advocate triangular PPP in a three-economy world of the US, PRC and Euroland. A weak form of PPP for the RMB euro exchange rate is confirmed by the results in Table 1, indicated by one cointegration vector. Moreover, both standard triangular PPP and simple triangular PPP in their weak form are confirmed by the results in Table 1, given the established cointegration relationships. The results are consistent with all three CPI measures. These results are reinforced by unit root tests. Both ADF and PP tests reject the null of a unit root with all three CPI measures for strong form PPP for the RMB euro exchange rate and strong form standard triangular PPP for the dollar euro exchange rate, as indicated by the results in Table 2. The confirmation of strong form simple triangular PPP is marginal nonetheless. The null of a unit root is rejected for two CPI measures, measure 1 and measure 3; and the rejection is at a low 10% significance level. Overall, a strong form of PPP for the RMB euro exchange rate and a strong form of triangular PPP for the dollar euro exchange rate are

further established. There is no cointegration relationship between the dollar euro exchange rate and CPIs of the US and Euroland. The Johansen test results are peculiar, given three cointegration vectors, indicating the variables are "stationary" themselves. Moreover, both ADF and PP tests fail to reject a unit root, as reported in Table 2. Thus, PPP does not hold for the dollar euro exchange rate and the price levels in the US and Euroland in both strong and weak forms.

{Table 3}

{Table 4}

{Table 5}

Our analysis also dispels the so called puzzle of "internal depreciation and external appreciation of the RMB". Table 3, Table 4 and Table 5 show this with plain data. Inflation and exchange rate movements are presented in Table 3 and Table 4, while inflation differentials and exchange rate movements are contrasted in Table 5. Although the RMB has "externally" appreciated vis-à-vis the US dollar by 16.76% between July 2005 and April 2008, the RMB has "externally" depreciated vis-à-vis the euro by 11.05% in the same period. That is, relative to the euro, no such external appreciation had existed. Bear in mind that the puzzle architect has overlooked inflation in the respective economies also. Between July 2005 and April 2008, the PRC CPI had increased by 10.10%, 6.43% or 13.77% adopting the first, second or third CPI index; the US CPI increased by 9.98% in the same period. This is against relative PPP, though the loss of purchasing power relative to the US dollar is much smaller than the RMB's own inflation: 0.12%, 3.55% or 3.79% using the first, second or third index, reported in Table 5b. The RMB had depreciated by 11.05% against the euro during the same period, and it had depreciated more than relative PPP could warrant: 2.75% (10.10% – 7.35%), -0.92% (6.43% – 7.35%) or 6.42% (13.77% – 7.35%) using the first, second or third index. That is, the RMB had

over depreciated against the euro, which though might offset its appreciation against the US dollar unjustified by relative PPP. Therefore, there is no such puzzle as "internal depreciation and external appreciation of the RMB", which can't be sustained by theory as well as by practice. For the post crisis period, the RMB appreciated against both the US dollar and the euro "externally", accompanied by inflation that was lower than that in both the US and Euroland, Table 5a and Table 5b report. The plain data in Table 5c further demonstrates great departures from PPP for the dollar euro exchange rate and the price levels in the US and Euroland.

6. Summary

Motivated by a dazzling foreign exchange market in recent years, a triangular PPP hypothesis has been proposed in this paper. It is a response to addressing an emerging issue arising from the peg of the RMB to the US dollar. This emerging issue and the object in our study are in stark contrast to the issues and objects predominantly examined in the existing literature. Therefore, we depart from the traditional, standard models of exchange rate determination that can only work for small economies. With these models, the economy that adopts pegged exchange rate regimes plays no roles beyond its national borders, to which our thinking and analysis differ.

A triangular PPP effect is confirmed to exist that the dollar euro exchange rate becomes a function of CPI ratios between PRC and Euroland. Our results demonstrate mixed results for PPP as in the existing literature, but they are contrary to the general consensus in the literature that PPP holds for countries with flexible exchange rate regimes to a greater extent than for countries with fixed exchange rate regimes. In our cases, PPP does not hold for economies with flexible exchange rate regimes, but seems to hold for a country with pegged exchange rate regimes in relation to an economy whose currency is not being pegged. This gives rise to triangular PPP.

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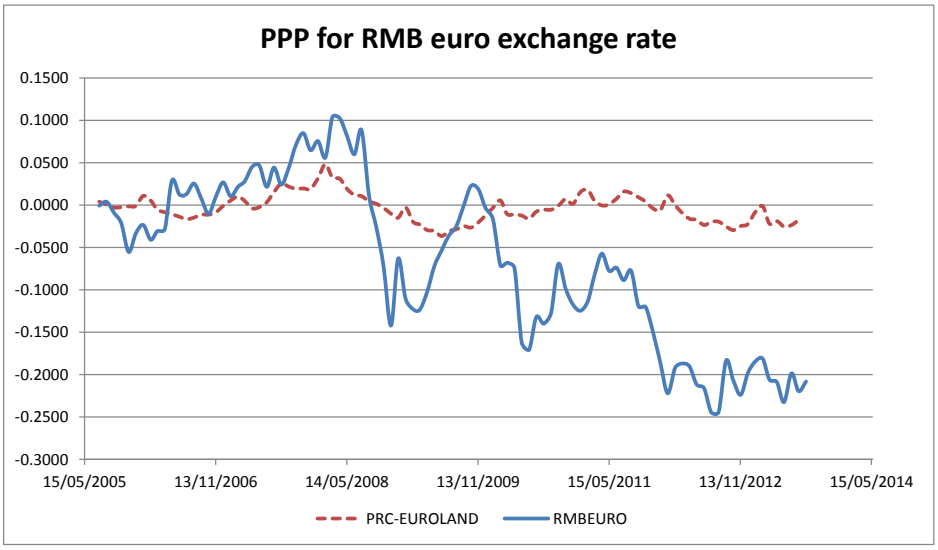
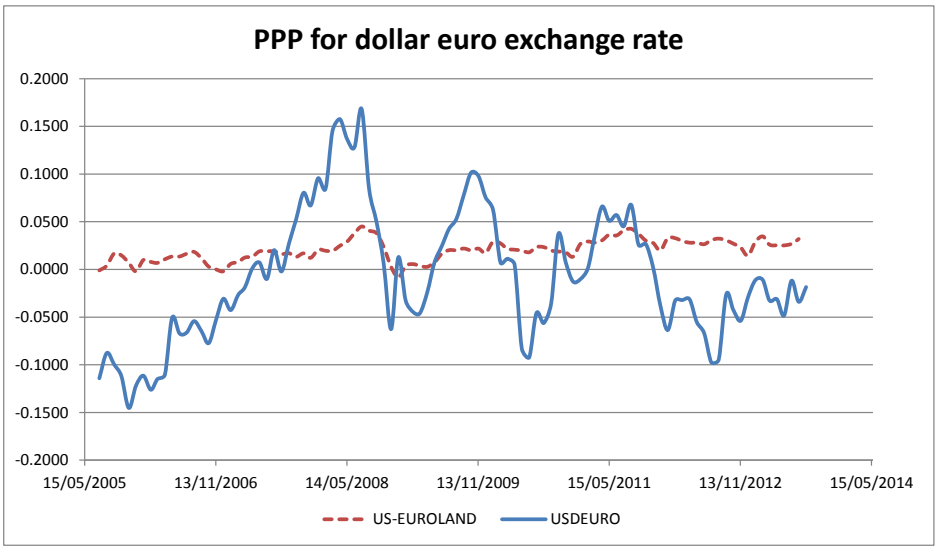




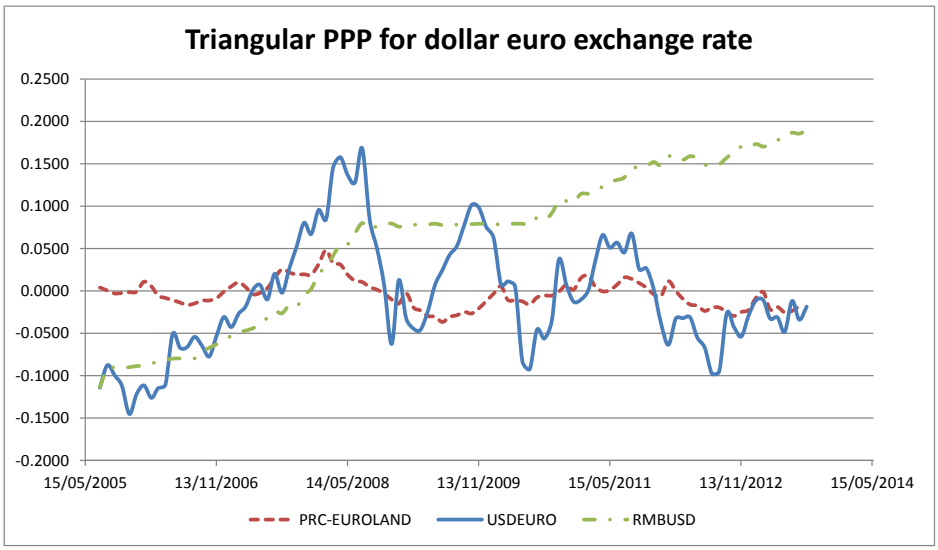
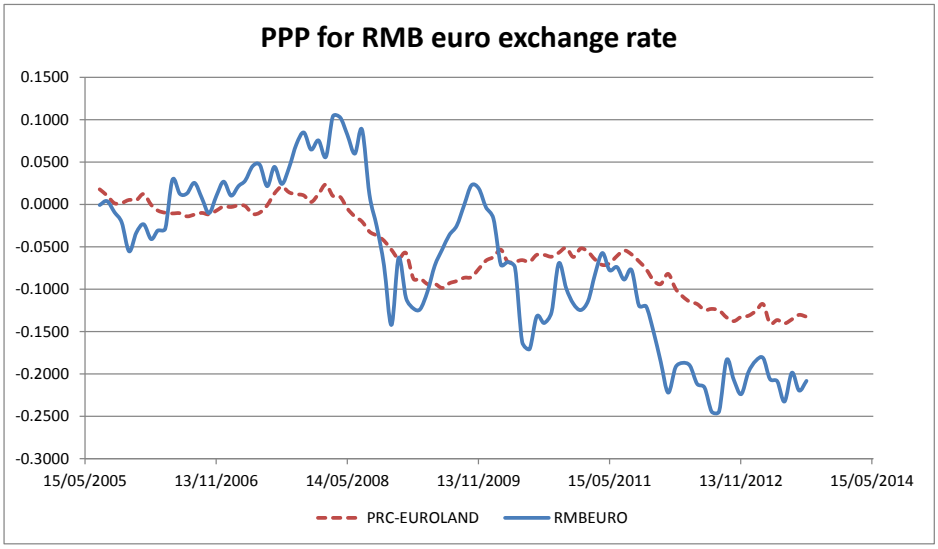


Figure 1. PPP and triangular PPP for the US, PRC and Euroland (with PRCCPI(1))



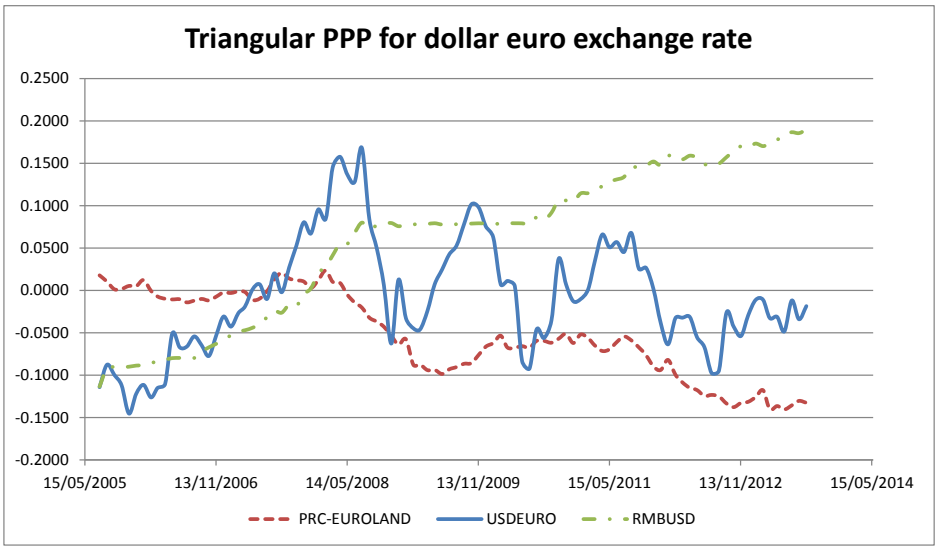
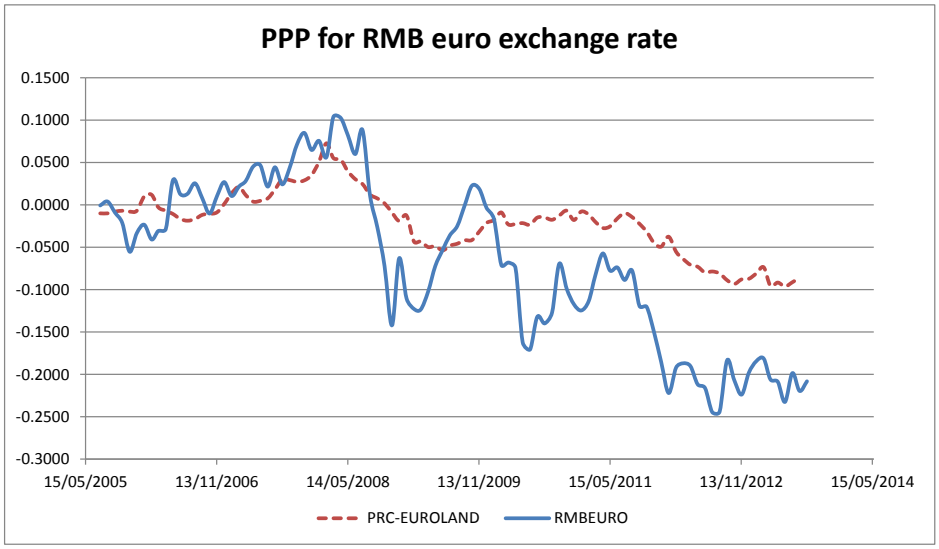


Figure 2. PPP and triangular PPP for the US, PRC and Euroland (with PRCCPI(2))



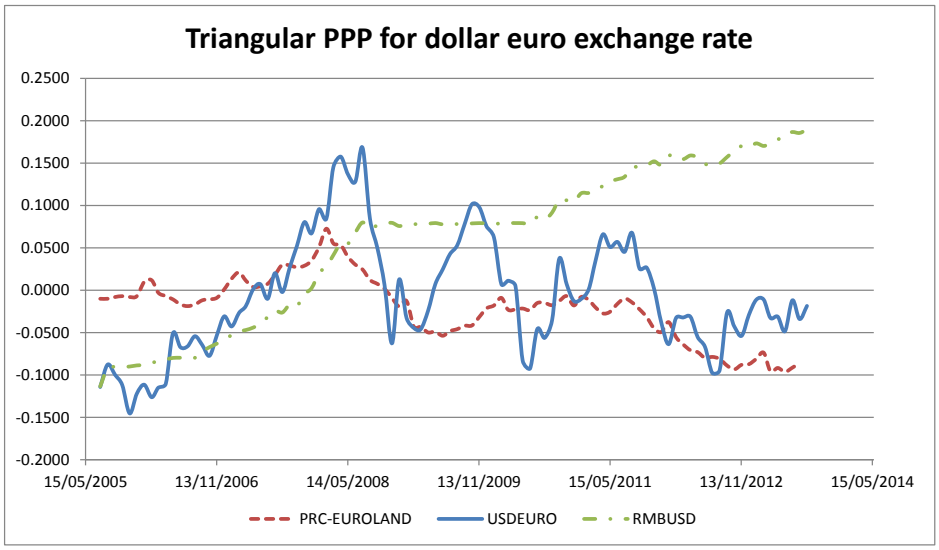


Figure 3. PPP and triangular PPP for the US, PRC and Euroland (with PRCCPI(3))

Table 1. Johansen cointegration tests for weak form PPP and weak form triangular PPP

		λ_{max}	Prob.	Trace	Prob.
PPP for	r = 0:	29.2358	0.0046	47.7053	0.0014
$e_{¥/€,t}$ (measure 1)	r = 1:	11.9345	0.1898	18.4695	0.0866
PPP for	r = 0:	25.8963	0.0150	42.0176	0.0079
$e_{¥/€,t}$ (measure 2)	r = 1:	10.7776	0.2687	16.1213	0.1688
PPP for	r = 0:	26.5199	0.0121	45.3386	0.0029
$e_{¥/€,t}$ (measure 3)	r = 1:	12.6082	0.1534	18.8187	0.0780
Standard triangular PPP	r = 0:	41.8995	0.0006	73.6561	0.0004
for $e_{\$/€,t}$ (measure 1)	r = 1:	21.8847	0.0571	31.7566	0.1121
Standard triangular PPP	r = 0:	48.8672	0.0000	80.0020	0.0001
for $e_{\$/€,t}$ (measure 2)	r = 1:	21.9493	0.0559	31.1347	0.1284
Standard triangular PPP	r = 0:	44.3581	0.0002	73.5642	0.0004
for $e_{\$/€,t}$ (measure 3)	r = 1:	19.4645	0.1188	29.2061	0.1915
Simple triangular PPP	r = 0:	35.6594	0.0018	49.8127	0.0089
for $e_{\$/€,t}$ (measure 1)	r = 1:	7.4020	0.8715	14.1533	0.6450
Simple triangular PPP	r = 0:	28.2874	0.0232	44.3043	0.0360
for $e_{\$/€,t}$ (measure 2)	r = 1:	9.4917	0.6731	16.0169	0.4912
Simple triangular PPP	r = 0:	27.0079	0.0348	46.6642	0.0201
for $e_{\$/€,t}$ (measure 3)	r = 1:	12.6575	0.3564	19.6563	0.2438

Table 2. Tests for strong form PPP and strong form triangular PPP

	ADF	PP
$\varepsilon_{\$€,t}$	-2.4598	-2.4966
$\varepsilon_{¥€,t}$ or $\varepsilon_{¥€\$,t}$ (measure 1)	-3.9819**	-3.1401*
$\varepsilon_{¥€,t}$ or $\varepsilon_{¥€\$,t}$ (measure 2)	-3.1983*	-3.2386*
$\varepsilon_{¥€,t}$ or $\varepsilon_{¥€\$,t}$ (measure 3)	-4.8074***	-3.5644**
$\varepsilon'_{¥€\$,t}$ (measure 1)	-2.8063*	-2.8284*
$\varepsilon'_{¥€\$,t}$ (measure 2)	-2.4815	-2.4323
$\varepsilon'_{¥€\$,t}$ (measure 3)	-2.7423*	-2.6888*

* reject a unit root at the 10% level, ** at the 5% level, *** at the 1% level

Table 3. Inflation developments

Time period		PRCCPI(1)	PRCCPI(2)	PRCCPI(3)	EUROCPI	USCPI
July 2005 –	Average	0.31%	0.19%	0.42%	0.22%	0.30%
April 2008	Cumulative	10.10%	6.43%	13.77%	7.35%	9.98%
April 2008 –	Average	0.06%	-0.08%	-0.08%	0.14%	0.16%
July 2013	Cumulative	3.67%	-5.34%	-5.34%	8.54%	9.30%
July 2005 –	Average	0.14%	0.01%	0.09%	0.17%	0.20%
July 2013	Cumulative	13.77%	1.09%	8.43%	15.90%	19.27%

Table 4. Exchange rate movements

Time period		¥/$	$/€	¥/€
July 2005 –	Average	-0.51%	0.85%	0.33%
April 2008	Cumulative	-16.76%	28.10%	11.05%
April 2008 –	Average	-0.22%	-0.23%	-0.46%
July 2013	Cumulative	-14.32%	-14.50%	-29.14%
July 2005 –	Average	-0.31%	0.13%	-0.19%
July 2013	Cumulative	-29.72%	12.33%	-17.98%

Table 5a. Inflation differentials and exchange rate movements: RMB and euro

Time period		PRCCPI(1)-EUROCPI	PRCCPI(2)–EUROCPI	PRCCPI(3)–EUROCPI	¥/€
July 2005 –	Average	0.09%	-0.03%	0.20%	0.33%
April 2008	Cumulative	2.75%	-0.92%	6.42%	11.05%
April 2008 –	Average	-0.08%	-0.22%	-0.22%	-0.46%
July 2013	Cumulative	-4.87%	-13.88%	-13.88%	-29.14%
July 2005 –	Average	-0.03%	-0.16%	-0.08%	-0.19%
July 2013	Cumulative	-2.13%	-14.81%	-7.47%	-17.98%

Table 5b. Inflation differentials and exchange rate movements: RMB and dollar

Time period		PRCCPI(1)-USCPI	PRCCPI(3)–USCPI	PRCCPI(3)–USCPI	¥/$
July 2005 –	Average	0.01%	-0.11%	0.12%	-0.51%
April 2008	Cumulative	0.12%	-3.55%	3.79%	-16.76%
April 2008 –	Average	-0.10%	-0.24%	-0.24%	-0.22%
July 2013	Cumulative	-5.63%	-14.64%	-14.64%	-14.32%
July 2005 –	Average	-0.06%	-0.19%	-0.11%	-0.31%
July 2013	Cumulative	-5.50%	-18.18%	-10.84%	-29.72%

Table 5c. Inflation differentials and exchange rate movements: dollar and euro

Time period		USCPI - EUROCPI	$/€
July 2005 –	Average	0.08%	0.85%
April 2008	Cumulative	2.63%	28.10%
April 2008 –	Average	0.02%	-0.23%
July 2013	Cumulative	0.76%	-14.50%
July 2005 –	Average	0.03%	0.13%
July 2013	Cumulative	3.37%	12.33%