Is there a rule of thumb for absolute purchasing power parity to hold?

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Abstract: We find an example where real exchange rate (RER) is stationary and the nominal exchange rate and the price levels are cointegrated but purchasing power parity (PPP) does not hold, which reveals a fault of the unit root and cointegration tests in this use. We argue that the distribution of an RER misalignment can be used in testing absolute PPP. Then we apply this new test and the coefficient restriction test to study the validity of absolute PPP in 40 main countries and areas (versus the US) in light of the Harrod-Balassa-Samuelson effect. The econometric proofs show that absolute PPP holds or closely holds in most countries when their averaged relative GDP per capita (GDPPs, against the US with the US = 1) are greater than 0.7. And it does not hold in almost all countries when their averaged GDPPs are smaller than 0.7. Thus, a rule of thumb for the theory to hold is that the GDPP should be above 0.7.

Keywords: Absolute purchasing power parity; Real exchange rate; RER misalignment distribution test; Harrod-Balassa-Samuelson effect

JEL Classification: F30; F31

1. Introduction

Purchasing power parity (PPP) dominates the determination of exchange rate and whether PPP holds has been extensively studied; see the review by Rogoff (1996) and Taylor and Taylor (2004). In popular studies (e.g., Lothian and Taylor, 1996; Pedroni, 2004; Chang and Tzeng, 2011; Astorga, 2012; Chang et al., 2012), the real exchange rates (RERs) are constructed by consumer, producer, wholesale, and other price indexes rather than actual price levels. Such constructed RER is used in testing relative PPP rather than absolute PPP (Cheung et al., 2005, p. 1153). Given that if absolute PPP holds then relative PPP must hold, but not vice versa (Taylor and Taylor, 2004, p. 137), absolute PPP is more basic. In addition, the empirical studies on absolute PPP are scarce. Therefore, in this paper, we construct RERs by actual price levels and study absolute PPP. Concretely, we focus on the following two issues, using basic econometric methods but from a different view.

First, we discuss which econometric method should be used in testing absolute PPP. In popular studies, economists apply up-to-date unit root and cointegration tests to test PPP, and the econometric methods evolve from the classical Dickey-Fuller unit root test to the current unit root test that accounts for breaks or nonlinearity and from the classical Engle-Granger or Johansen cointegration test to the current threshold or panel cointegration test, using time series or panel data dimension. In these studies, whether in classical or current tests, PPP is accepted when RER is stationary or there is a cointegration relationship between nominal exchange rate (NER) and price indexes. In this paper, however, we construct an artificial example to show that the unit root and cointegration tests in this use may have an obvious fault. Further, we propose a new test, the RER misalignment distribution test, and argue that the new test and the commonly used coefficient restriction test can avoid such a fault.

Second (and mainly), by applying the coefficient restriction and RER misalignment distribution tests to the bilateral RERs of 40 main countries and areas against the US, we examine the conditions for absolute PPP to hold. It is well known that absolute PPP does not hold between a poor country and a rich country because of the Harrod-Balassa-Samuelson (HBS hereafter) effect (Rogoff, 1996; Taylor and Taylor, 2004). But, as far as we know, how the HBS effect influences the validity of absolute PPP is unclear. Frenkel (1981, p.146) says, "Much of the controversy concerning the usefulness of the PPP doctrine is due to the fact that it does not specify the precise mechanism by which exchange rates are linked to prices nor does it specify the precise conditions that must be satisfied for the doctrine to be correct." In this paper, we investigate the second issue mentioned by Frenkel (1981), the precise conditions for the absolute PPP theory to hold, given that this issue is seldom addressed in the last thirty years' research although it has an important policy and theoretical significance.

The rest of the paper is organized as below. Section 2 discusses which econometric method should be used and presents the data used. Section 3 gives the empirical results for the countries where absolute PPP holds or closely holds. Section 4 gives the empirical results for the countries where absolute PPP does not hold. Finally, Section 5 concludes the paper. In the following text, "PPP" refers to "absolute PPP" (absolute PPP theory) except when specifically stated otherwise.

2. Methodology and data

In this paper, the RER is defined by Eq. (1), where P_i is the domestic (general) price level of country i, P^* is the price level of the specific foreign country (in this paper, the United States), PPP_i rate is P_i divided by P^*, and NER_i is expressed as the domestic currency units per fixed foreign currency unit (the domestic currency price of one US dollar). In this definition, a greater value of *RER* represents the local currency's appreciation (against the US dollar), and the value of *RER* will be equal to 1 if PPP holds. Further, the misalignment, under or –overvaluation, is measured by the difference of *RER* minus 1 (misalignment = *RER* – 1). In this paper, all variables are in their original form (not logarithmic) throughout.

$$RER_i = \frac{PPP_i}{NER_i} = \frac{P_i/_{P^*}}{NER_i} \tag{1}$$

2.1. Methodology

2.1.1. The low power of the unit root and cointegration tests

Engel (2000) and Taylor et al. (2001) have studied the low power of the standard unit root and cointegration tests in relative PPP. The low power of the unit root and cointegration tests in absolute and relative PPP can also be found in the artificial example as below (Fig. 1).

Suppose we have two countries, country X and the US. Country X adopts the US dollar as its domestic currency like the US, thus the NER between the two countries is 1:1.

Case (a):

The price level of country X is not changeable: $P_t = 2$, for t = 0, 1, 2, ...

The price level of the US is not changeable: $P_t^* = 1$, for t = 0, 1, 2, ...

Thus, the RER is also not changeable: RER_t (= PPP_t = P_t) = 2, for t = 0, 1, 2, ...

Case (b):

The price level of country X at year t: $P_t = 2 + 0.2 \times t$, for t = 0, 1, 2, ...

The price level of the US at year t: $P_t^* = 1 + 0.1 \times t$, for t = 0, 1, 2, ...

Thus, the RER at year t: $RER_t\ (= PPP_t) = 2$, for t = 0, 1, 2, ...

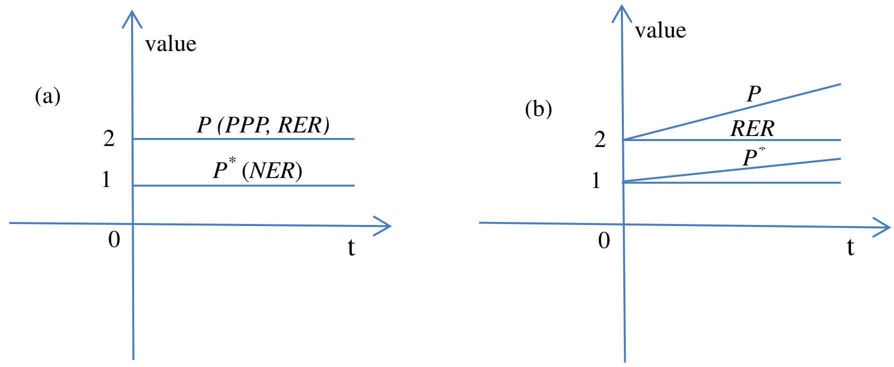

Fig. 1. Country X's exchange rates against the US.

In case (a), since each variable is constant, it must be (strictly) stationary. Further, the RER is stationary and there is a cointegration relationship between the NER and the price levels (stationary series must be cointegrated; actually, they exceed the cointegration because their arbitrary linear combination is stationary). However, the RER's value is invariably two, twice its equilibrium value (one), so absolute PPP does not hold.

In case (b), P and P^* are trend stationary (non-stationary), and *NER* is stationary, but there is a cointegration relationship among the P, P^*, and *NER* ($P = 2 \times P^*$). Simultaneously, the RER is also stationary. As in case (a), absolute PPP does not hold because the value of the RER is always two. In addition, relative PPP does not hold either because the ratio of the changes of the two countries' price levels is not equal to the change of the NER (the US's price level increases 20% per year, country X's price level increases 10% per year, but the NER is invariable.).

These are two cases where the RER is stationary and the NER and price levels are cointegrated but PPP does not hold: in case (a), absolute PPP does not hold but relative PPP holds; in case (b), neither absolute nor relative PPP holds. In the two cases, neither breaks nor nonlinearity appear. Thus, neither the stationarity of the RER nor the cointegration relationship between the NER and price levels is a sufficient condition for PPP to hold.

Comparatively and in detail, PPP in popular studies appears in its various weak versions (as specifically stated in Pedroni (2004)), but PPP in this paper is presented in its strict version. Thus, though the unit root and cointegration tests can be (and have been broadly) applied in testing PPP in popular studies, as just shown in the above Fig. 1, they are not appropriate in this paper. Thus, we rely on the coefficient restriction and RER misalignment distribution tests, which can be free of the above fault in the unit root and cointegration tests.

2.1.2. Coefficient restriction test

The coefficient restriction test (so called the proportionality and symmetry test) has been broadly used in popular PPP studies, such as in Edison et al. (1997) and Ito (1997). But the coefficient restriction test used in this paper is slightly different from that used in popular studies, which can be seen in the above Eq. (1): (1) the prices in popular studies are price indexes but those in this paper are actual price levels and (2) the variables in popular studies are logarithmic but those in this paper are in their original forms.

The coefficient restriction test (the null hypothesis: $\beta_0 = 0$ and $\beta_1 = 1$) is performed on Eq. (2), where we regress the NER on the PPP rate. But as a preliminary, we still need to test the stationarity and cointegration relationship of the NER and PPP rate series to avoid spurious regression. We use the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test to examine whether or not a series is stationary. If both the NER and PPP rate are stationary, we use OLS with Newey-West robust standard error to estimate Eq. (2). If they are not stationary, we apply the Engle-Granger or Johansen method to test for a cointegration relationship between them. If they are cointegrated, FMOLS with Bartlett kernel and Newey-West fixed bandwidth is used. For the coefficient restriction test in Eq. (2), we use the Wald test. Concretely, if the *p*-value for the χ^2 statistic in the Wald test is greater than 0.05, we accept the null hypothesis $\beta_0 = 0$ and $\beta_1 = 1$ and say that PPP holds. If the *p*-value is less than 0.05, we reject the null hypothesis and say that PPP does not hold.

$$NER_t = \beta_0 + \beta_1 PPP_t + u_t \tag{2}$$

It can be seen that, if we use the coefficient restriction test on the two cases in the artificial example in Section 2.1.1, we will have $\beta_0 = 0$ and $\beta_1 = 0.5$ and the test will reject PPP. Thus the coefficient test is free of the fault existing in the unit root and cointegration tests. In addition, since stationary variables surpass cointegration and the non-stationary variables in this paper are all cointegrated, the coefficient restriction test used in this paper actually already includes the cointegration test. However, Fig 1 has told us that, even though cointegration is a necessary condition for PPP to hold, cointegration itself is not enough in testing PPP in this paper. In other word, coefficient restriction must be applied after we confirm a cointegration relationship in a non-stationary case.

2.1.3. RER misalignment distribution test

A basic usefulness of PPP is its application in currency valuation. Thus, in our opinion, the distribution of the RER misalignment (over- or undervaluation) also matters in measuring the validity of PPP. But how to use the RER misalignment distribution to measure the validity of PPP is unclear. In our opinion, if a RER misalignment (= $RER - 1$) is close to a normal distribution with a mean of zero, which means that the NER regularly fluctuates around the PPP rate, PPP holds. The nearer a normal distribution of zero mean for a RER misalignment, the more valid it is for PPP to hold for this RER. “Normal distribution” insures that the RER misalignment is centered on the mean and the distribution is regular. “Zero mean” insures that over- and undervaluation are offset and equilibrium is realized. A mean less than 0.1 (in absolute value, as below) may be viewed as “very near” zero and a mean greater than 0.1 may be viewed as “far from” zero.

Concretely, we use the following criterion which is a bit subjective. If an RER misalignment is normally distributed and its mean is less than 0.1, we think that PPP holds. If an RER misalignment is normally distributed and its mean is greater than 0.1, we think that PPP does not hold. If an RER misalignment is not normally distributed, though the misalignment mean still can indicate the under- or overvaluation to some extent, we think that the misalignment distribution is irregular and whether or not PPP holds for this RER cannot be decided by this test. Big changes in economy can make the RER misalignment distribution abnormal, such as in Brazil and Chile (see Section 4.2). In the norm distribution test, if the *p*-value for the Jarque-Bera (JB) statistic is greater than 5%, we accept the null hypothesis that the misalignment is normally distributed. If the *p*-value for the JB statistic is less than 5%, we think that the misalignment distribution is not normal. As an application, if we apply the misalignment distribution test to the two cases in the artificial example in Section 2.1.1, we will have a (reduced) normal misalignment distribution but with a mean of 1 in each case and the test will reject PPP. Thus the RER misalignment distribution test is also free of the fault existing in the unit root and cointegration tests.

As two tests (the coefficient restriction and RER misalignment distribution tests) are used, the conclusions from them may be not consistent in any case. The result is not debatable in the case where the two tests give the same conclusions. That is, if the two tests both accept PPP, PPP holds; if the two tests both reject PPP, PPP does not hold. For the case where one test accepts PPP, but the other test rejects it (e.g., in Section 3.1), we think that PPP closely holds. For the case where the RER misalignment distribution test cannot decide, if the coefficient restriction accepts (or rejects) PPP, we think that PPP holds (or does not hold) (e.g., in Section 3.1).

In addition, whether PPP holds between two countries is what we care more about, and the panel data dimension cannot distinguish the individual character and difference among the countries. Therefore, we use the time series data econometric method. Concretely, we use the (time series) coefficient restriction and RER misalignment distribution tests in this paper.

2.2. Data

All data are from the World Bank's World Development Indicators (WDIs) online database that supplies most updated data and University of Pennsylvania's Penn World Table (PWT) 7.1 online database that supplies longer term data from 1950–2010.

We first sequence all the global countries (and areas) by their GDPs in 2012 (in constant 2005 US dollars) and in the WDI database, and choose the largest 41 among them; the GDP of each country represents greater than 0.3% of that of the world. Then, for these countries, we collect the bilateral RERs and GDP per capita (GDPPs) of the 40 countries against the US. The WDI supplies GDPPs (the indicator name "GDP per capita, PPP (constant 2005 international $)" and the indicator code "NY.GDP.PCAP.PP.KD" in the database) and RERs (the indicator name "PPP conversion factor (GDP) to market exchange rate ratio" and the indicator code "PA.NUS.PPPC.RF" in the database) in 1980–2012. The PWT supplies GDPPs (the description "PPP Converted GDP Per Capita (Chain Series), at 2005 constant prices", the unit "2005 International dollar per person (2005 I$/person)", and the variable name "rgdpch" in the database) and RERs (the description "Price Level of GDP, G-K method (US = 100)", the unit "US=100", and the variable name "p" in the database; divided by 100 in this paper) in 1950–2010. But the concrete values for GDPPs and RERs in the two databases are not exactly the same. We combine a variable's value in 2010 in the PWT and its growth ratios in 2011–2012 in the WDI to obtain the consistent values in 2011–2012. For example, the GDPP of the US was 41365 in 2010 in the PWT, and it was 42001, 42447, and 43063 in 2010, 2011, and 2012 respectively in the WDI. We treat the value of the GDPP in 2011 as 41804 (= 41365 × (42447/42001)) and that in 2012 as 42411 (= 41804 × (43063/42447)) respectively. Using the same method we obtain the consistent RERs in 2011–2012. Such obtained values of GDPPs and RERs in 2011–2012 and those in 1950–2010 in the PWT constitute the total values in the whole period 1950–2012. Since the NERs in the two databases are the same in the two databases, the PPP rates are obtained from the consistent RERs and NERs. For convenience, the GDPPs are all normalized, with the US = 1; the RERs are already normalized (with the US = 1) according to Eq. (1).

In addition, some notes about the data should be given. For euro countries, the NERs are of the same currency (euro) after they adopted the euro. For China, version 1 in the PWT is used. Though the longest period is 1950–2012, for some concrete countries, the available periods are shorter because the data on some years are blank. The 40 bilateral RERs are of the 40 largest countries and areas (Australia, Austria, Belgium, Brazil, Canada, Chile, China, Colombia, Denmark, Finland, France, Germany, Greece, Hong Kong, India, Indonesia, Ireland, Israel, Italy, Japan, Korea, Malaysia, Mexico, Netherlands, Nigeria, Norway, Poland, Portugal, Russian Federation, Saudi Arabia, Singapore, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, United Arab Emirates, United Kingdom, Venezuela) against the United States.

3. PPP holds or closely holds

We divide the countries discussed in this section into three groups. In the first group, PPP does not hold in a country's lower income level period when the averaged GDPP is smaller than 0.7, but holds or closely holds in the country's higher income level period when the averaged GDPP is greater than 0.7. In the second group, PPP holds or closely holds in each country whose GDPP is greater than 0.7 in the whole period. In the third group, PPP closely holds in the (single) country whose GDPP is smaller than 0.7 in the whole period.

3.1. The countries whose GDPPs in higher income level periods are greater than 0.7

It is well known that the Harrod-Balassa-Samuelson effect (HBS effect hereafter) would cause PPP to be invalid, which can be seen from Table 3 and Figure 3 in Rogoff (1996, pp. 659–660) or from Figure 3 in Isard (2007, p. 13). HBS effect as used in this paper refers to the phenomenon where, measured by a common currency, rich countries tend to have higher price levels and poor countries tend to have lower price levels. Thus, it can also be generally termed as the Penn effect, no matter whether the phenomenon is caused by the inter-country difference in traded goods productivities or by other reasons (Isard, 2007, p. 12, the last paragraph). Given the HBS effect, we expect that PPP does not hold in a country's lower income level period but holds in the country's higher income level period. Indeed, we find such countries. These countries are Austria, Belgium, Ireland, Italy, and the UK. We use Austria to illustrate.

Table 1

The HBS effects in the Austria type of countries.

Country	Sample	Relative GDP per capita (the US = 1)		RER (the US = 1)	
		Mean	Rang (Min., Max.)	Mean	Rang (Min., Max.)
Austria	1950–1975	0.66	(0.45, 0.85)	0.55	(0.46, 0.81)
	1976–2012	0.87	(0.82, 0.94)	0.95	(0.60, 1.21)
Belgium	1950–1975	0.68	(0.56, 0.84))	0.73	(0.65, 1.06)
	1976–2012	0.82	(0.77, 0.87)	1.01	(0.65, 1.27)
Ireland	1950–1990	0.51	(0.42, 0.60)	0.65	(0.49, 0.97)
	1991–2012	0.81	(0.59, 0.97)	1.06	(0.82, 1.38)
Italy	1950–1980	0.60	(0.40, 0.78)	0.60	(0.47, 0.88)
	1981–2012	0.74	(0.65, 0.82)	0.92	(0.60, 1.17)
UK	1950–1980	0.68	(0.64, 0.73)	0.73	(0.56, 1.18)
	1981–2012	0.75	(0.65, 0.83)	0.97	(0.69, 1.20)

Sources: PWT 7.1, WDI and the authors' calculation.

First, let's confirm the HBS effect in the five countries. Table 1 gives the changes of the relative GDP per capita (GDPPs) and RERs of the five countries. For each country, we divide the whole period into two sub-periods according to the change of the GDPP. For Ireland, its GDPP was always less than 0.7 before 1990, so we divide the whole period by using 1990 as the cutoff point. For the other four countries, the cutoff point is 1975 or 1980. For Austria, from 1950–1975 to 1976–2012, the GDPP increases both in the mean, from 0.66 to 0.87, and in the range, from 0.45 to 0.82 in the minimum and from 0.85 to 0.94 in the maximum respectively. As the GDPP increases, the RER also increases. That is, from 1950–1975 to 1976–2012, the RER increases both in the mean, from 0.55 to 0.95, and in the range, from 0.46 to 0.60 in the minimum and from 0.81 to 1.21 in the maximum respectively. Similar conclusions can also be obtained in the cases of the other four countries. Thus, there is an HBS effect in each country.

Fig. 2 gives a graphic description of Austria, where the GDPP, RER, NER, and PPP rate in 1950–2012 are depicted in the top two figures and the histogram and descriptive statistics of the RER misalignment distribution in 1976–2012 are depicted in the bottom figure. In the top left figure, we can see the HBS effect (though the RER fluctuates much). In the top right figure, we can see that, in 1950–1975, the NER is mostly far above the PPP rate, which indicates that PPP may not hold. In 1976–2012, however, the NER approaches and fluctuates around the PPP rate, which indicates that PPP may hold in this period.

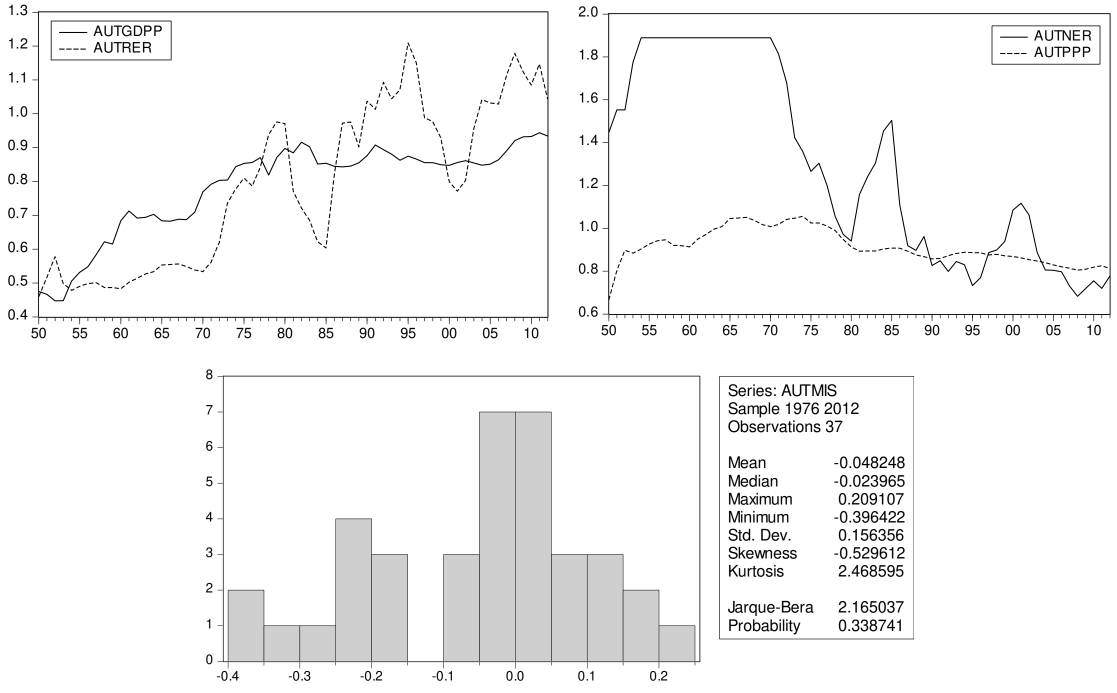

Fig. 2. The exchange rates and relative GDPP of Austria in different periods.

Notes: The prefix "AUT" with each name represents Austria, thus "AUTGDPP", "AUTRER", "AUTNER", "AUTPPP", and "AUTMIS" refer to the country's GDPP, RER, NER, PPP rate, and RER misalignment respectively.

Sources: PWT 7.1, WDI and the authors' calculation.

Then we turn to the formal econometric tests. Table 2 shows that, in the lower income level period 1950–1975, the p-value for the JB statistic is zero, which means that the RER misalignment distribution is not normal, thus whether or not PPP holds cannot be decided by this test based on our criteria (see Section 2.1.3). However, the p-value for the χ^2 statistic is also zero, so the Wald coefficient restriction test rejects the null hypothesis that PPP holds (see Section 2.1.2). Combining the conclusions from both the RER misalignment distribution and Wald tests, we think that PPP does not hold in 1950–1975 based on our criteria (see Section 2.1.3). In the higher income level period 1976–2012, the RER misalignment is normally distributed and the mean (-0.05) is very near zero (see the bottom figure of Fig. 2), thus the RER misalignment distribution test accepts PPP. However, the Wald test still rejects PPP at the 0.05 level. Thus, PPP closely holds in 1976–2012. In detail, the RER misalignment mean (-0.45) in 1950–1975 is far from zero than that in 1976–2012 (-0.05), and the Wald test cannot accept PPP at any level in 1950–1975 but can accept PPP at the 0.03 level in 1976–2012. That is, even if other criteria are used in the two tests (e.g., another significant level (0.01 or 0.1) different from the 0.05 that we use), the proofs can also give the same conclusion, that PPP is obviously more valid in 1976–2012 than in 1950–1975.

Table 2

Econometric tests for the Austria type of countries.

Country	Period	Estimate Eq. (2): OLS or FMOLS	Wald coefficient restriction test: χ^2 statistic (P-value)	RER misalignment distribution test: Mean	RER misalignment distribution test: JB statistic (P-value)
Austria	1950–1975	OLS	215.19 (0.00)	-0.45	20.09 (0.00)
	1976–2012	OLS	6.75 (0.03)	-0.05	2.17 (0.34)
Belgium	1950–1975	OLS	823.76 (0.00)	-0.27	35.36 (0.00)
	1976–2012	OLS	0.84 (0.66)	0.01	1.94 (0.38)
Ireland	1950–1990	FMOLS	109.25 (0.00)	-0.35	6.00 (0.05)
	1991–2012	OLS	8.15 (0.02)	0.06	1.58 (0.45)
Italy	1950–1980	OLS	806.17 (0.00)	-0.40	4.34 0.11
	1981–2012	OLS	11.35 (0.00)	-0.08	1.76 (0.42)
UK	1950–1980	FMOLS	203.11 (0.00)	-0.27	49.03 (0.00)
	1981–2012	OLS	5.59 (0.06)	-0.03	2.41 (0.30)

Sources: PWT 7.1, WDI and the authors' calculation.

Table 2 also gives the econometric tests for the other four countries (Belgium, Ireland, Italy, and the UK). For Belgium and the UK, the Wald test rejects PPP, but the RER misalignment distribution test cannot give a definite conclusion in the lower income level periods (Belgium's period 1950–1975 and the UK's period 1950–1980); the two tests, however, both accept PPP in the higher income level periods (Belgium's period 1976–2012 and the UK's period 1981–2012). Thus, considering the two tests, PPP does not hold in the two countries' lower income level periods but holds in the two countries' higher income level periods. For Ireland and Italy, the two tests both reject PPP in the lower income level periods (Ireland's period 1950–1990 and Italy's period 1950–1980). In the higher income level periods (Ireland's period 1991–2012 and Italy's period 1981–2012), the Wald tests still reject PPP, but the RER misalignment distribution tests accept PPP. Thus, PPP does not hold in the two countries' lower income level periods but closely holds in the higher income level periods, as in Austria.

In summary, for the five countries, in the lower income periods (when the averaged GDPPs are less than 0.7), PPP does not hold. However, in the higher income periods (when the averaged GDPP are greater than 0.7), PPP holds or closely holds. This gives the HBS effect's modification to PPP. That is, as the GDPP increases, the validity of PPP increases.

3.2. The countries whose GDPPs (in whole periods) are greater than 0.7

This group includes Australia, Canada, Denmark, France, Germany, Norway, Sweden, and Switzerland. They all have an income level near that of the US; the averaged GDPP is greater than 0.7 in each whole period. We use Canada as an illustration.

Fig. 3 gives a graphic description of Canada, where the GDPP, RER, NER, and PPP rate in 1950–2012 are depicted in the top two figures and the histogram and descriptive statistics of the RER misalignment distribution in the same period are depicted in the bottom figure. In the top left figure, we can see that the GDPP fluctuates around the value of about 0.85 and the RER fluctuates around the value of about 0.95, thus there is no HBS effect. In the top right figure, we can see that the NER fluctuates around the PPP rate, which indicates that PPP may hold. When turning to the formal econometric tests, the bottom figure shows that the RER misalignment is a normal distribution with a mean of -0.04, thus the RER misalignment distribution test accepts PPP. In addition, the coefficient restriction test (in Table 3) marginally accepts or rejects PPP. Considering the two tests, PPP holds or closely holds for Canada.

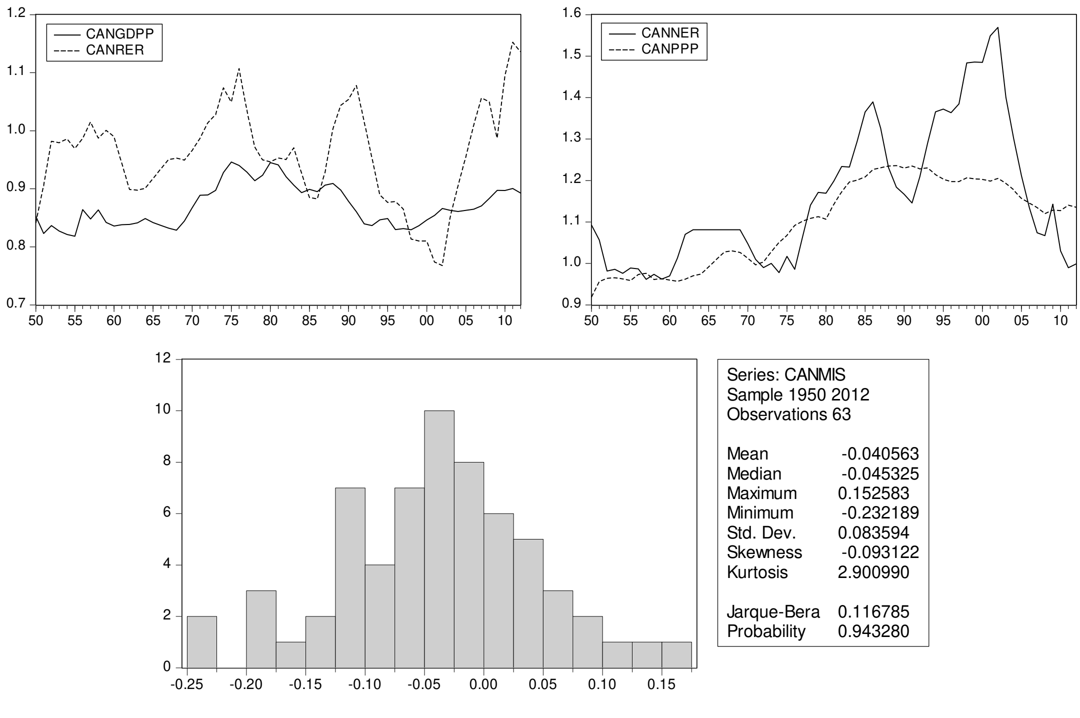

Fig. 3. The exchange rates, GDPP and RER misalignment of Canada from 1950 to 2012.

Notes: The prefix "CAN" with each name represents Canada. Other notes of the names are similar to those in Fig.2.

Sources: PWT 7.1, WDI and the authors' calculation.

Table 3 also gives the econometric tests for the other seven industrial countries (Australia, Denmark, France, Germany, Norway, Sweden, and Switzerland). For France and Germany, both the coefficient restriction and RER misalignment distribution tests accept PPP, thus PPPs hold for the two countries. For Australia, Denmark, Norway, Sweden, and Switzerland, the coefficient restriction test rejects PPP, but the RER misalignment distribution test accepts it; thus, PPP closely holds in these five countries.

Table 3

Econometric tests for the Canada type of countries and for Venezuela.

Country	Period	Estimate Eq. (2): OLS or FMOLS	Wald coefficient restriction test: χ^2 statistic (P-value)	RER misalignment distribution test		Relative GDP per capita (the US = 1)	
				Mean	JB statistic (P-value)	Mean	Rang (Min., Max.)
Australia	1950–2012	OLS	35.19 (0.00)	-0.10	4.01 (0.13)	0.91	(0.79, 1.01)
Canada	1950–2012	OLS	6.14 (0.047)	-0.04	0.12 (0.94)	0.87	(0.82, 0.95)
Denmark	1950–2012	OLS	332.42 (0.00)	0.07	5.91 (0.052)	0.80	(0.60, 0.89)
France	1950–2012	FMOLS	5.78 (0.06)	-0.07	5.01 (0.08)	0.74	(0.52, 0.89)
Germany	1970–2012	FMOLS	2.80 (0.25)	0.00	1.96 (0.38)	0.82	(0.75, 0.90)
Norway	1950–2012	OLS	125.90 (0.00)	0.02	3.52 (0.17)	0.99	(0.69, 1.25)
Sweden	1950–2012	OLS	37.10 (0.00)	0.06	4.01 (0.13)	0.86	(0.74, 0.99)
Switzerland	1950–2012	OLS	16.22 (0.00)	0.01	5.53 (0.06)	1.14	(0.87, 1.44)
Venezuela	1950–2012	FMOLS	2.73 (0.26)	-0.11	4.18 (0.12)	0.35	(0.18, 0.51)

Sources: PWT 7.1, WDI and the author's calculation.

Thus, in the 13 countries' (five countries in Section 3.1 and eight countries in Section 3.2) corresponding periods when the GDPPs are greater than 0.7, PPP holds or closely holds. That is, PPP holds or closely holds in the 13 countries that have an income level near to that of the US. This is coincidental to some extent with the finding of Taylor and Taylor (2004, pp. 138–139), who concluded that PPP did not hold *perfectly*, but held *reasonably well*, between the US and the UK in the periods 1820–2001 and 1791–2001.

3.3. The countries whose GDPP is smaller than 0.7

This group includes only one country, Venezuela. The econometric tests for Venezuela are also listed in the above Table 3. We can see that the RER misalignment mean (0.11, in absolute value) is greater than 0.1 (the cutoff point that we set), and the distribution is normal, thus the RER misalignment distribution test rejects PPP. But the coefficient restriction test accepts PPP.

Considering the two tests, PPP closely holds. Alternatively, as the mean is very near 0.1, we can also deem that the mean is equal to 0.1 and the RER misalignment distribution tests accepts PPP because the distribution is normal; then by combining the coefficient restriction test, we have the conclusion that PPP holds. That is, PPP holds or closely holds for this country.

Venezuela is a very special case. In contrast, for all the other countries when their averaged GDPPs are smaller than 0.7, PPP does not hold (see Sections 3.1, 4.1, and 4.2). For Venezuela, whose averaged and maximum GDPPs are both smaller than 0.7, however, PPP holds or closely holds. This country is the only counter-example of all of the countries whose GDPPs are smaller than 0.7. This special character about the validity of PPP in Venezuela is perhaps related to the country's particular economic system, as we can see in another petroleum-exporting country, the United Arab Emirates (see Section 4.1).

4. PPP does not hold

To focus on the goal of this paper, and as in the above Section 3, we classify different countries according to their GDPP levels, rather than their whole economic characters (such as the classification of developed and developing countries). Concretely, we classify the countries in this section where PPP does not hold into two groups: the countries whose GDPPs are greater than 0.7 and those whose GDPPs are smaller than 0.7.

4.1. The countries whose GDPPs are greater than 0.7

This type of countries includes Finland, Hong Kong, Japan, the Netherlands, Singapore, and the United Arab Emirates. Japan, Finland, Hong Kong, and Singapore all have a higher income level period when the averaged GDPP is greater than 0.7, and the averaged GDPP of the Netherlands and the United Arab Emirates is greater than 0.7 in the whole period, but PPP does not hold for all of them. We use Japan and the United Arab Emirates to illustrate.

Fig. 4 gives a graphic description of the GDPPs and RERs of Japan (from 1950 to 2012) and the United Arab Emirates (from 1986 to 2011). We can see that, in Japan, the GDPP increases from about 0.2 to about 0.8, and the RER increases from less than 0.4 to about 1.2, which shows an HBS effect. In the United Arab Emirates, the GDPP decreases from 2.1 to 1.4, but the RER increases slowly from less than 0.6 to 0.96. Thus, the change of the RER and GDPP of the United Arab Emirates shows a reverse HBS effect.

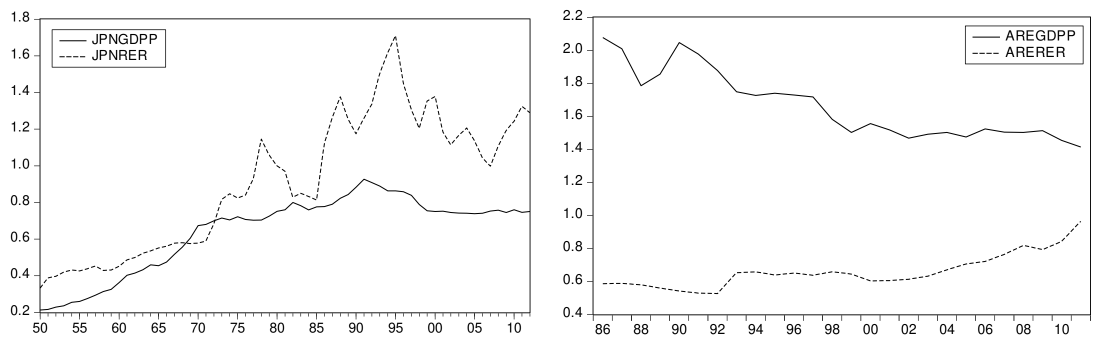

Fig. 4. The RERs and GDPPs of Japan and the United Arab Emirates.

Notes: The prefixes "JPN" and "ARE" among each name represent Japan and the United Arab Emirates respectively.

Sources: PWT 7.1, WDI and the authors' calculation.

Table 4 gives the econometric tests for Japan, the United Arab Emirates, and the other four countries. For Japan, both the coefficient restriction and RER misalignment distribution tests reject PPP in its lower income level period (1950 to 1980) and in its higher income level period (1981 to 2012), thus PPP does not hold. Though the RER misalignment distribution tests reject PPP for Japan, the RER misalignment distribution in the higher income level period is more near a normal distribution with zero mean than in the lower one, which can be seen from the means and *p*-values. This again indicates the HBS's modification to PPP to some extent. Similar conclusions can also be obtained for Finland, Hong Kong, and Singapore. For the Netherlands, both the coefficient restriction and RER misalignment distribution tests reject PPP, thus PPP does not hold. For the United Arab Emirates, the RER misalignment test cannot give a definite conclusion, but the coefficient restriction test rejects PPP, thus PPP does not hold either.

Table 4

Econometric tests for the Japan and United Arab Emirates type of countries.

Country	Period	Estimate Eq. (2): OLS or FMOLS	Wald coefficient restriction test: χ^2 statistic (P-value)	RER misalignment distribution test		Relative GDP per capita (the US = 1)	
				Mean	JB statistic (P-value)	Mean	Rang (Min., Max.)
Finland	1950–1980	OLS	22.64 (0.00)	-0.16	4.68 (0.10)	0.61	(0.45, 0.76)
	1981–2012	OLS	6.99 (0.03)	0.14	1.11 (0.57)	0.75	(0.65, 0.83)
Hong Kong	1960–1985	OLS	70.54 (0.00)	-0.31	2.79 (0.25)	0.40	(0.21, 0.60)
	1986–2012	OLS	214638.3 (0.00)	-0.15	1.79 (0.41)	0.77	(0.61, 0.96)
Japan	1950–1980	OLS	665.66 (0.00)	-0.39	5.29 (0.07)	0.49	(0.21, 0.75)
	1981–2012	OLS	12.20 (0.00)	0.21	0.01 (0.99)	0.79	(0.74, 0.93)
Netherlands	1950–2012	OLS	18.80 (0.00)	-0.22	5.54 (0.06)	0.87	(0.67, 0.98)
Singapore	1960–1985	OLS	105.14 (0.00)	-0.36	2.25 (0.32)	0.43	(0.26, 0.69)
	1986–2012	OLS	56.58 (0.00)	-0.24	1.72 (0.42)	0.95	(0.62, 1.38)
United Arab Emirates	1986–2011	OLS	41501662 (0.00)	-0.34	7.05 (0.03)	1.67	(1.41, 2.08)

Sources: PWT 7.1, WDI and the authors' calculation.

Thus, in the six countries' periods (Finland's and Japan's periods 1981 to 2012, Hong Kong's, Singapore's, and the United Arab Emirates' periods 1986 to 2012, and the Netherlands' period 1950 to 2012) when the averaged GDPPs are greater than 0.7, PPP does not hold. These six countries are the counter-examples in the countries where PPP should hold in the periods when the averaged GDPPs are greater than 0.7 according to the proposed rule of thumb.

4.2. The countries whose GDPPs are smaller than 0.7 (mostly smaller than 0.4)

The number of this type of countries is 20 and their averaged GDPPs are all smaller than 0.7 (mostly smaller than 0.4). Except for the maximum value of Israel's GDPP (0.71), which is slightly greater than 0.7, the maximum of the other countries' GDPPs are all smaller than 0.7. For these countries, we use two members of the G20, Brazil and India, to illustrate.

Fig. 5 gives the GDPPs and RERs of Brazil and India from 1950 to 2012. For the two countries, their GDPPs are (much) smaller than 0.7 and do not increase obviously in the whole periods; the GDPP of Brazil is always smaller than 0.3 and that of India is always smaller than 0.1. For Brazil, though the RER is indeed near 1 in the early 1950s and in some years around 2010, it is mostly smaller than 0.6 from 1960 to 2004 (and the mean is 0.64 in the whole period). For India, the RER decreases from 0.86 to about 0.3. Thus, seen from the figures, there is almost no HBS effect and PPP may not hold for the two countries.

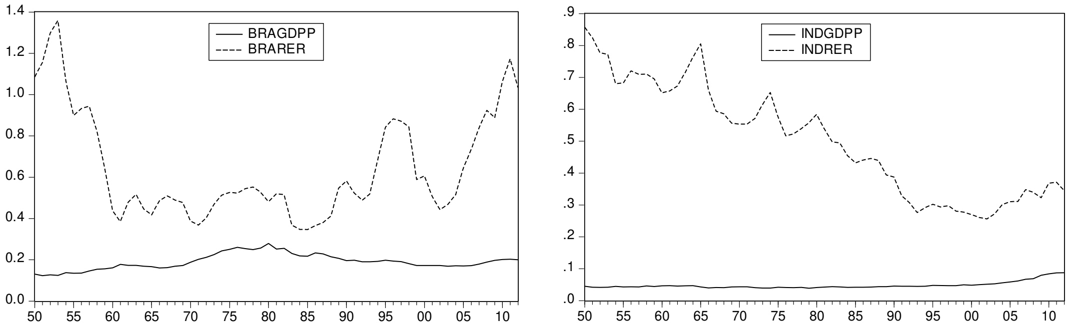

Fig. 5 The RERs and GDPPs of Brazil and India.

Notes: The prefixes "BRA" and "IDN" among each name represent Brazil and India respectively.

Sources: PWT 7.1, WDI and the authors' calculation.

Table 5 gives the econometric tests for Brazil, India, and the other countries of this type. For Brazil, the RER misalignment distribution test cannot give a definite conclusion (the RER misalignment again enters the dead zone of its distribution test, as seen in above sections), but the coefficient restriction test rejects PPP, thus PPP does not hold. Similar conclusions can also be obtained for the other eight countries (Chile, China's period 1981–2012, Colombia, Greece, Israel, Nigeria, Portugal, and Turkey). For India and the other 11 countries (China's period 1952–1980, Indonesia, Korea, Malaysia, Mexico, Poland, Russia, Saudi Arabia, South Africa, Spain, and Thailand), both the RER misalignment distribution and coefficient restriction tests reject PPP, thus PPP does not hold for these countries either. In a word, PPP does not hold for all the 20 countries in the table.

Table 5

Econometric tests for the Brazil and India type of countries.

Country	Period	Estimate Eq. (2): OLS or FMOLS	Wald coefficient restriction test: χ^2 statistic (P-value)	RER misalignment distribution test		Relative GDP per capita (the US = 1)	
				Mean	JB statistic (P-value)	Mean	Rang (Min., Max.)
Brazil	1950–2012	FMOLS	10.18 (0.006)	-0.36	10.66 (0.005)	0.19	(0.12, 0.28)
Chile	1951–2012	FMOLS	125.97 (0.00)	-0.12	41.34 (0.00)	0.22	(0.15, 0.32)

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Table 5 (continued)

Country	Period	Estimate Eq. (2): OLS or FMOLS	Wald coefficient restriction test: χ^2 statistic (P-value)	RER misalignment distribution test		Relative GDP per capita (the US = 1)	
				Mean	JB statistic (P-value)	Mean	Rang (Min., Max.)
China	1952–1980	FMOLS	1733.8 (0.00)	0.40	2.34 (0.31)	0.02	(0.01, 0.02)
	1981–2012	OLS	97.85 (0.00)	-0.52	29.82 (0.00)	0.08	(0.02, 0.20)
Colombia	1950–2012	FMOLS	90.64 (0.00)	-0.30	30.48 (0.00)	0.18	(0.15, 0.20)
Greece	1951–2012	FMOLS	23.44 (0.00)	-0.33	6.15 (0.046)	0.53	(0.26, 0.69)
India	1950–2012	FMOLS	403.06 (0.00)	-0.50	4.27 (0.12)	0.05	(0.04, 0.09)
Indonesia	1960–2012	FMOLS	28.81 (0.00)	-0.45	0.87 (0.65)	0.06	(0.03, 0.10)
Israel	1950–2011	FMOLS	16.47 (0.00)	-0.08	1343.56 (0.00)	0.55	(0.30, 0.71)
Korea	1953–2012	OLS	128.39 (0.00)	-0.41	2.69 (0.26)	0.30	(0.10, 0.66)
Malaysia	1955–2012	OLS	51.41 (0.00)	-0.26	2.73 (0.25)	0.17	(0.09, 0.30)
Mexico	1950–2012	FMOLS	382.07 (0.00)	-0.47	3.02 (0.22)	0.31	(0.25, 0.43)
Nigeria	1950–2012	FMOLS	24.51 (0.00)	-0.35	9.80 (0.01)	0.06	(0.03, 0.10)
Poland	1970–2012	OLS	54.29 (0.00)	-0.50	0.52 (0.77)	0.31	(0.24, 0.42)
Portugal	1950–2012	OLS	32.98 (0.00)	-0.35	6.47 (0.04)	0.40	(0.21, 0.51)
Russia	1990–2012	OLS	21.14 (0.00)	-0.56	1.06 (0.59)	0.29	(0.20, 0.40)
Saudi Arabia	1986–2012	OLS	2482248 (0.00)	-0.25	2.32 (0.31)	0.49	(0.40, 0.58)
South Africa	1950–2012	FMOLS	64.34 (0.00)	-0.31	0.07 (0.96)	0.21	(0.15, 0.26)
Spain	1950–2012	OLS	94.43 (0.00)	-0.36	4.82 (0.09)	0.57	(0.29, 0.69)
Thailand	1950–2012	OLS	312.33 (0.00)	-0.51	0.79 (0.67)	0.11	(0.05, 0.20)
Turkey	1950–2012	FMOLS	45.52 (0.00)	-0.24	69.73 (0.00)	0.21	(0.17, 0.27)

Sources: PWT 7.1, WDI and the authors' calculation.

It should be noted that Chile and Israel both have a highly priced RER, near or even greater than 1 in some periods (Chile's period 1951 to 1982 and Israel's periods 1950 to 1961 and 1988 to 2011). Although the RER is priced lower in other periods, each RER mean in the whole period is more than 0.85 (Chile's 0.88 and Israel's 0.92). Thus, the averaged RER misalignment in the two countries is not as far from zero as in the other countries. For China, though the GDPP was always very low in the whole period, the GDPP increased very obviously after the country's reform and openness in the later 1970s. Thus we divide the country's whole period into two sub-periods, 1952–1980 and 1981–2012. As China changed its exchange rate policy greatly in the two sub-periods, the RER misalignment also displays greatly different pictures in the two sub-periods.

In retrospect, besides the 20 countries in this section, PPP does not hold in the lower income level periods of the nine countries discussed above (Austria, Belgium, Ireland, Italy, and the UK in Section 3.1; Finland, Hong Kong, Japan, and Singapore in Section 4.1) either. Thus, PPP does not hold in every period of the 29 countries when the averaged GDPP is smaller than 0.7. There is only one counter-example, Venezuela (see Section 3.3).

In addition, that PPP does not hold when the GDPP is smaller than 0.7 can also be proven in a panel data setting. Concretely, if we stack all these 40 countries' time series variables into a panel, the panel-averaged GDPP is 0.53, the coefficient restriction rejects PPP, the RER misalignment mean is -0.21 and the distribution is not normal, and therefore PPP does not hold either.

5. Conclusion and some further discussions

Economists popularly apply various unit root and cointegration tests to study PPP in its weak versions. In these studies, if RER is stationary or the NER and the price indexes are cointegrated, PPP is accepted. However, we find an example where RER is stationary and the NER and the price levels are cointegrated but PPP in its strict version does not hold. This shows that commonly used unit root and cointegration tests in testing the weak-version PPP are not appropriate in testing the strict-version PPP that is discussed in this paper. Alternatively, we propose a new, simple method in this use, the RER misalignment distribution test. Then, we apply this new test and the coefficient restriction test, which are both free of the fault existing in the unit root and cointegration tests, to examine the 40 main bilateral RERs against the US for the condition of the validity of PPP from the perspective of the HBS effect.

The econometric tests show that PPP holds or closely holds in most countries (13 out of 19) when their GDPPs (on average in the periods, against the US with the US = 1) are greater than 0.7, and the theory does not hold in almost all the countries (29 out of 30) when their GDPPs are smaller than 0.7. This suggests that the GDPP level of 0.7 can be viewed as a rough threshold for the validity of PPP: if the GDPP is smaller than 0.7, PPP does not hold; if the GDPP is greater than 0.7, PPP holds. However, this threshold is not hard and fast, because there are indeed a few countries (7 out of the total 40 in this paper) that do not obey this rule in some periods. That is, strictly speaking, this is not a necessary or sufficient condition for PPP to hold. Or this is only a necessary but not sufficient condition if petroleum exporting countries are excluded.

In addition, the empirical conclusions in the paper are robust when some criteria in the tests are changed. For example, if we change the cutoff point of the mean in the RER misalignment distribution test from 0.1 to 0.15 and leave other criteria unchanged, PPP will change from not holding to closely holding in the higher income level periods of Finland (1981–2012) and Hong

Kong (1985–2012), with the other countries not being affected. We will have two more expected countries that meet the proposed rule. If we change the significance level in the coefficient restriction test from 0.05 to 0.01, only the conclusions for Brazil and Finland are obviously changed. Concretely, Brazil will change from being an expected example to being a counter-example of the proposed rule, but Finland (in 1981–2012) will change from being a counter-example to being an expected one.

In the end, the GDPP level of 0.7 for PPP to hold is only a rule of thumb. One may argue that the threshold (if it exists) is not 0.7, but is 0.6, 0.69, 0.75, or another value. One may also argue that the threshold of 0.7 (if it exists) obtained in this paper is unconvincing: the sample countries are not large enough, the causality between the threshold and the economic fundamentals is unclear, the conclusion obtained in this paper may depend on the data and method used, and so on. All the relevant issues can be studied further.

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