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PURCHASING POWER PARITY IN LESS-DEVELOPED AND TRANSITION ECONOMIES: A REVIEW PAPER

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Abstract. The concept of purchasing power parity (PPP) has been the subject of numerous studies, many of which have been unable to prove conclusively this core principle of international finance. Although industrialized countries have received most of the attention, studies that focus on less-developed and transition economies have also attained mixed results. This study surveys trends in this branch of the literature, highlighting the econometric advances that have sought to solve this puzzle, while pointing out that more needs to be done to address the reasons that might cause PPP not to hold.

Keywords. LDCs; Purchasing power parity; Transition economies

1. Introduction

The concept of purchasing power parity (PPP) is a fundamental principle in international economics. Attributed to Cassel (1916), but dating back even further, PPP provides a simple definition of exchange-rate determination: that an exchange rate equalizes the price of goods between countries. Although the related 'law of one price' stipulates that each specific good should cost the same worldwide once the currencies are converted, this clearly does not hold due to such factors as trade barriers and transport costs. PPP instead focuses on general price levels and their relationship to the nominal exchange rate. The theory is put forth that exchange rates should equalize their respective countries' price levels:

$$E = \frac{P}{P^*} \tag{1}$$

where E is the nominal exchange rate in terms of home to foreign currency, P is the domestic price level and P^* is the foreign price level. Note that this is similar to the formulation of a real exchange rate as in equation (2) below, if the real rate were to equal 1 (i.e. one home basket of goods costs exactly one foreign basket of goods). This equation is often tested in log-linear form:

$$\ln E = \alpha + \beta \ln P + \gamma \ln P^* \tag{2}$$

where α is expected to equal zero, $\beta = 1$ and $\gamma = -1$. In empirical studies, this 'absolute' measure of PPP is generally rejected in the short run. In the long

Journal of Economic Surveys (2009) Vol. 23, No. 4, pp. 617–658

run, the results are more mixed. Froot and Rogoff (1996) show that shocks to the exchange rate are long-lasting – they do not return quickly to the equilibrium level that the relative price levels would indicate. That study has unleashed numerous examinations of PPP for nearly every conceivable country pair in the world. Deviations from equilibrium are long-lasting, leading variables to return to PPP only slowly – if at all.

In short, whereas PPP should clearly hold in theory, it has been difficult to demonstrate empirically. This 'PPP puzzle' has perplexed numerous economists, who, rather than reject the theory, have assumed that the relationship exists but is not being detected. Others have sought to explain the reasons behind these deviations.

One attempt to solve the problem is by relaxing the assumptions. Economists have been able to distinguish between 'absolute' PPP, where the nominal exchange rate is exactly equal to the ratio between the two countries' price level, and 'relative' PPP, where the difference between the two is related to the difference between the countries' inflation rates,

$$\%\Delta E = \%\Delta P - \%\Delta P^* \tag{3}$$

thus allowing for PPP to fail if countries are experiencing varying inflation. Even when allowing this flexibility, PPP has not always been proven. Although the developed world, especially the G-7 and Organization for Economic Cooperation and Development (OECD) countries, has received most of the attention, various less-developed countries (LDCs) and transition economies have also been studied. These studies have also arrived at mixed results.

Various explanations have been provided for the 'failure' of PPP to hold empirically, such as the use of price indices such as the consumer price index (CPI) that include non-traded goods, which would not allow arbitrage to take place to equalize prices. Another theory behind the failure of PPP involves productivity differentials, known as the Balassa–Samuelson effect. According to this theory, low wages in a low-productivity, labour-endowed country will cause prices to be low in its non-traded sector, whereas high wages will drive prices up in a more productive economy. Higher productivity will thus cause an appreciation in a country's real exchange rate and can lead to a breakdown in PPP. In LDCs, where productivity tends to be lower, this effect might provide a particularly useful explanation. In post-communist transition economies, which had suffered severe reductions in output beginning in the late 1980s, the 'productivity bias' has been of interest in studies of PPP. Bahmani-Oskooee and Nasir (2005) discuss and provide a detailed review of the productivity bias hypothesis.

Other studies provide detailed explanations for the PPP puzzle. Bahmani-Oskooee and Goswami (2003) list a number of factors explaining the breakdown of PPP, including natural resources endowments and corruption, as well as introducing their own explanation – smuggling. Many of these problems affect LDCs more than they do developed countries. Bahmani-Oskooee and Goswami (2005a), for example, find that military spending contributes to the failure of PPP in 37 LDCs.

PPP is an important concept for LDCs for other reasons as well – it is said to provide more accurate comparisons of living standards in poor, labour-endowed countries than is possible when incomes are measured in dollars, for example. Thus, it is useful to examine the relevant studies regarding LDCs and transition economies to ascertain whether PPP is in fact a valid assumption.

Much of the PPP literature has been summarized well by Sarno and Taylor (2002) and A.M. Taylor and Taylor (2004), who concentrate on specific issues highlighted by the wide range of previous analyses performed, mainly for industrial countries. In this paper we attempt to provide an examination of PPP in LDCs and transition economies, which proceeds as follows. In Section 2, we discuss the main issues that pertain to LDCs and transition economies in studying PPP. In Section 3, we survey the literature regarding PPP in less-developed and transition economies according to the econometric techniques each employs. Section 4 provides a conclusion.

2. Issues Specific to PPP in LDCs and Transition Economies

2.1 *Data Issues*

In many developing countries, especially in Africa, data can be infrequently collected, not entirely accurate, or simply unavailable. Attempts to overcome the problem of short time series generally involve using more years, such as in Kargbo (2003a, 2004). This approach has the drawback that these spans tend to include more structural shifts, such as changes in the exchange-rate regime, which are likely to have taken place over the course of decades. Alternatively, studies have applied different techniques, such as panel data approaches, which focus on cross-sectional variation as well and can thus accommodate a short time span.

Even when the available data are monthly or quarterly, some series may still be lacking. The wholesale price index (WPI), which is considered to be optimal for studies of PPP because of its higher proportion of traded goods, often is not available, especially in Africa. As a result, the debate over which is the optimal price index must be ignored, because there is only one option for the price index. If, as such studies as McNown and Wallace (1989) and Liu (1992) have shown, using the CPI rather than the WPI causes PPP to be rejected, then many studies of LDCs will fall victim to this lack of data. Because Wu and Chen (1999) arrive at the opposite result, however (PPP holds using CPI, but not WPI), perhaps it is possible to set the debate aside in the interest of exploring the issue at hand with the data available.

Often the varying availability of data for all of the countries in a single study imposes other limitations. For example, Lee (1999) is only able to use the CPI for 11 of 13 countries and the WPI for 12. The situation is worse for Liu (1992), who has WPI data only for six of nine countries. Khoon and Mithani (2000) lose half their time span when they shift from CPI to WPI! Thus, economists who study LDCs might have to rely on a less-desirable data set or curtail their estimation because the first-best variable makes the study unfeasible.

2.2 *Inflation and LDCs*

Once a shock is introduced to the nominal exchange rate–relative price level relationship, the variables will have to adjust if PPP is going to hold. Rapid changes in price levels might provide a mechanism to do this. Because LDCs and certain transition economies often face higher inflation rates than their developed counterparts, they provide an excellent opportunity to study the theory that higher inflation leads to faster adjustment towards the long-run PPP equilibrium. Studies that have explicitly examined this idea for LDCs, including McNown and Wallace (1989), Achy (2003) and Alba and Papell (2007), note that differing inflation rates may be a determining factor in explaining deviations from PPP. Thus, LDCs themselves add to the literature by allowing this idea to be tested more comprehensively.

2.3 *Effective and Black-market Exchange Rates*

Although most empirical studies employ some nominal bilateral exchange rate in their analyses, there is considerable difference in what is considered to be the most appropriate rate. Although the bilateral rate with the US dollar is often the most convenient, conflicting results are often found when bilateral rates with different trade partners are compared side by side. The 'base country' effect has been noted in previous reviews, drawing attention to this disparity.

One solution to this problem is to incorporate all trading partners of a country in testing PPP by using the effective exchange rate rather than the bilateral rate. Bahmani-Oskooee and Rhee (1992) and Bahmani-Oskooee (1993b) do so, and because the data are not always available via conventional sources, Bahmani-Oskooee (1995) and Bahmani-Oskooee and Mirzaie (2000) create data sets of nominal and real effective exchange rates and use them to test the PPP hypothesis. The use of the effective rates often uncovers less evidence for the relationship than do tests using bilateral rates, however.

Another choice of exchange rate is the black-market, rather than the nominal, exchange rate. Because many LDCs and transition economies have had restrictions on foreign currencies, these currencies would become more expensive on the black market. This black-market rate would thus reflect actual supply and demand pressures within the country, and tests of PPP in this context may demonstrate whether the markets for foreign currency are efficient. Studies that incorporate the black-market exchange rate include Bahmani-Oskooee (1993b), Phylaktis and Kassimatis (1994), El-Sakka and McNabb (1994), Sanchez-Fung (1999), Kargbo (2003a), Chortareas and Kapetanios (2004), Bahmani-Oskooee and Goswami (2005b), Kargbo (2006), Cerrato and Sarantis (2006, 2007) and Bahmani-Oskooee and Tanku (2007). Bahmani-Oskooee and Gelan (2006a) show that the black-market, but not the official, exchange rate supports the productivity bias hypothesis for the countries in their sample, thus helping to explain one further source of deviations from PPP.

Some of the relevant data, including the time span and frequency of the data and the choice of exchange rate and price index for each study, are described in the

tables throughout this review. All in all, these considerations show that LDCs and transition economies are worthy of a separate study, as these countries face their own specific issues that the developed world does not.

2.4 *Issues Specific to Transition Economies*

Although they suffer from many of the same problems as Latin American, Asian and African LDCs, the transition economies of Europe and (Central) Asia also present a particular set of considerations. First of all, the time period since the fall of communism has been less than two decades. Even with the increasing availability of quarterly data, the number of observations available for time-series analysis is small. Furthermore, the main variables of interest in studies of PPP, namely exchange rates and prices, were tightly controlled under socialism. Currencies (if a country even had its own currency) were often inconvertible; prices were often fixed at highly distorting levels. Because these have been liberalized, they have experienced an adjustment trajectory and speed much different from what might be considered typical. Likewise, transition economies have seen their trade flows reoriented towards the West, an increase in the proportion of non-traded goods, formerly government enterprises at least partially privatized and a massive increase in capital inflows and foreign investment. All of these play a role in the overall economic climate.

An even more important contributor to a breakdown in PPP is the productivity differentials that have been mentioned previously. Following the fall of communism, transition economies underwent a large drop in output as their existing capital stock was found to be uncompetitive compared to Western firms. Because much (but not all) of the region's productive capacity has been rebuilt during this period, these countries should show a trend appreciation in their currencies that will show up in empirical studies as a breakdown in PPP. As a result, these transition economies not only have a unique economic history, they also have definite explanations for why PPP might not hold.

3. Empirical Tests of PPP in LDCs and Transition Economies

As was stated previously, one explanation for the PPP puzzle is that econometric techniques are unable to detect the phenomenon. Thus, as these techniques have been refined, they have been applied to PPP in an attempt to uncover evidence for the phenomenon. Although a handful of studies, such as Adler and Lehmann (1983), apply simpler techniques such as ordinary least squares to studies of PPP in LDCs, and others apply less common techniques (such as the principal components approach of Holmes, 2001a), most studies apply modern time-series techniques to PPP. Some time-series methods are more difficult to classify – including the ARIMA-based study of Wallace and Shelley (2006), or the autoregressive approach that Cashin and McDermott (2006) use to examine the speed of reversion in the exchange rates of 90 countries – but most can be categorized into one of four categories: linear unit root, cointegration, panel and nonlinear.

Although a number of studies examine only the basic property of stationarity – only a stationary variable will return to its equilibrium value after a shock, and thus adhere to PPP – cointegration analysis and panel approaches can be more informative. As these techniques have been shown to have certain weaknesses, more recent studies have applied nonlinear tests. Others have focused on the 'speed of adjustment', determining how long it takes for variables to revert to their equilibrium values. Completely novel approaches are less frequently applied to LDC data; most often a theoretical paper will use G-7 or OECD data to test its hypotheses. Thus, many of these papers apply familiar techniques to new countries.

Here, we provide an overview of the literature, focusing on how econometric techniques have been used to attempt to solve the PPP puzzle and whether these attempts were ultimately successful in finding support for PPP. Although the speed of adjustment has been measured in many studies, we focus more on the simple fact of whether or not support for PPP is found and what factors might underlie these results.

3.1 *Linear Unit-root Tests of PPP*

Linear unit-root tests are among the most simple and straightforward of time-series tests of PPP. Sometimes, the components of the real exchange rate are evaluated separately, but more often the nominal exchange rate and relative prices are evaluated for stationarity as a single real rate:

$$R = \frac{E \times P^*}{P} \tag{4}$$

If the real exchange rate is stationary, PPP might hold as the variables never drift apart and the relationship remains. The alternative is a random walk, where any shock to the variable is not dampened and the variable never reverts to its mean. If this is the case, the exchange rate is not solely determined by the relative price level. Thus, testing for mean reversion versus a random walk is the first step in evaluating the possibility of PPP. A number of tests are available for this, the best known of which is the Dickey–Fuller test. It tests the null hypothesis of a random walk by assessing whether a variable follows the following autoregressive process:

$$X_t = \rho X_{t-1} + \varepsilon_t \tag{5a}$$

with a null of $|\rho| = 1$, which is a 'unit root'. If equation (5a) is rewritten by subtraction as in

$$\Delta X_t = (\rho - 1)X_{t-1} + \varepsilon_t \tag{5b}$$

then it is possible to test whether $\rho - 1 = 0$. Either way, failure to reject the null hypothesis for an exchange rate indicates that the variable follows a random walk and that PPP cannot hold. Other tests include the augmented Dickey–Fuller (ADF) test, the KPSS test of Kwiatkowski, Phillips, Schmidt and Shin (1992); and the Phillips–Perron (PP) test. The KPSS test involves a null hypothesis of stationarity

rather than a null of a unit root. One advantage of the PP test is that it corrects for autocorrelated residuals and is thought to be more powerful than other tests.

One major criticism of the unit-root test is its low power: it tends to fail to reject the null of the unit root if the process is slowly mean reverting (for example, being unable to discern between $\rho = 0.95$ and $\rho = 1$). As a result, the test often completely rejects PPP even when the phenomenon actually exists. Incorporating structural breaks, which allows the mean to move and thus allow a variable to revert to a new mean, or using a more sophisticated test might allow a more accurate assessment of the presence or absence of a unit root.

The choice of unit-root test has an important effect on the results obtained. Bahmani-Oskooee (1995), after compiling comprehensive series of nominal and real effective exchange rates for 22 LDCs, uses them in a study of PPP. Using the ADF unit-root test, he finds that PPP fails to hold for most (14 of 22) of the countries. Bahmani-Oskooee (1998), however, applies the KPSS test as well as the ADF test on the real and nominal effective exchange rates of 11 Middle Eastern countries, which include Egypt and Tunisia from the earlier paper. Here, the KPSS test supports PPP for eight of the 11 countries. Although Tunisia's exchange rate has a unit root in both studies, the KPSS test reveals a stationary process for Egypt where the ADF had found none.

Lee (1999), studying 13 Asia-Pacific countries, also shows that an alternative test may provide less evidence of a unit root and thus support PPP. Although only Mexico is shown by the PP test to contain a unit root, a dynamic, non-standard error-correction unit-root test provides more evidence of PPP – support is found for six out of 12 countries using the CPI as the measure of the price level, and eight out of 11 using the WPI. Using simply the PP test, Doğanlar and Özmen (2000) find no support for PPP in 18 LDCs in Latin America, Africa and Asia. Using only the ADF test, Khoon and Mithani (2000) reject PPP for Malaysia. Although these tests often provide contradictory results, their low power tends to reject PPP in the majority of cases. Bahmani-Oskooee and Mirzaie (2000) find that the KPSS test performs better. After constructing nominal and real effective exchange rates for 20 LDCs, they perform both the ADF and KPSS tests and show that, whereas the former test rejects PPP for all but a few countries, the latter test finds support for most of them.

Solving the power problem of unit-root tests often limits the options available to test for PPP. Aggarwal *et al.* (2000) apply unit-root tests with structural breaks for seven of Japan's Asian trading partners, noting that more comprehensive cointegration tests could not capture these breaks. They find 'quasi PPP' – where the exchange rate returns to a shifted mean – when the bilateral rate with Japan is used. Another problem is highlighted, however: different results may be obtained when different countries' bilateral rates are compared. Here, less evidence for PPP is provided when the countries' bilateral rates with Germany, the USA and Australia are used.

Other methods used to counteract the low power of the ADF and PP tests are the fractional integration and variance ratio tests. Two studies use these methods, also determining which factors might account for PPP. Achy (2003) looks at the

real exchange rates of 38 middle-income countries. Although the ADF and PP tests fail to reject the null of non-stationarity for most of the countries, various structural changes are detected. The Perron structural break test finds various trend breaks, mean breaks and mean shifts for the various countries. Applying fractional integration methods, which allow for persistence and longer-lasting effects, gives different results – for all of the countries except Iran and Paraguay, the author finds evidence of parity reversion and thus PPP. Achy (2003) also explains the determinants behind the persistence of deviations from PPP: inflation speeds up reversion, as do fixed exchange-rate systems and capital mobility; but productivity growth increases make deviations last longer. Apergis (2003) rejects short-run PPP for Armenia via ordinary least squares (OLS) and unit-root tests, and long-run PPP with unit-root tests. Variance decomposition to determine the source of the deviation finds that it is due to supply shocks.

Further studies apply novel methodologies to single countries. These new techniques do not automatically uncover PPP, however. Payne *et al.* (2005) test for a unit root for Croatia using a Lagrange Multiplier (LM) unit-root test with a maximum of two endogenous structural breaks, but fail to find evidence of PPP. They attribute this to productivity growth and increasing wages, which would be consistent with the Balassa–Samuelson effect. Tastan (2005), applying the ADF and PP tests, as well as an Elliott *et al.* (1996) point-optimal test, finds that PPP in Turkey generally holds. Using monthly data over the period 1982–2003, the author shows support for PPP with bilateral rates with the UK and the USA, but arrives at mixed results when the Deutsche Mark and Italian lira are used. Abumustafa (2006), on the other hand, finds that the choice of base country does not matter for Jordan (with the USA, Japan and Germany), but that the test type does. Using the ADF and PP tests, PPP is shown to fail in all cases, but when the KPSS test is applied, PPP holds with a trend for all countries.

Recent studies also show that whereas certain tests often perform better than others, choosing a different test does not automatically uncover evidence for PPP. Akinboade and Makina (2006a) incorporate three endogenous structural breaks for South Africa and, using the ADF, KPSS and the PP additive outlier test (which tests for mean shifts), fail to find evidence of stationarity. These results are expanded upon by Akinboade and Makina (2006b), who find better evidence for PPP using the Perron and Vogelsang (1992) test that captures sudden shifts rather than gradual ones. In the most comprehensive study to date, Bahmani-Oskooee *et al.* (forthcoming) perform the KPSS on the real effective exchange rates of 113 countries, including 88 LDCs and transition economies. Most of the rates of these 24 Asian, 18 African, 25 European and 21 Latin American countries show evidence of stationarity, and thus support for PPP.

In sum, linear unit-root tests that assess whether a country's real exchange rate is stationary suffer from two main problems. The fact that a country might observe PPP with certain trading partners, but not with others, has been addressed in the literature, with most studies continuing to focus on a single bilateral rate. The low power of standard unit-root tests is of more concern, however. Although some tests seem to find more evidence of PPP, various innovations have been applied in

an attempt to improve the tests. Incorporating structural breaks and allowing for persistence and slow mean reversion are two methods by which the PPP puzzle might be solved via unit-root tests, but the reasons behind the breakdown of PPP need to be explored further. Table 1 summarizes each paper in this section and provides main features of each study in detail.

3.2 *Cointegration Tests of PPP*

More sophisticated than simple unit-root tests is cointegration analysis, which assesses whether a long-run relationship exists among a set of variables. Two variables may be non-stationary, but there might still exist a linear combination of the two that in itself is stationary. In other words, the variables might be integrated of order one, I(1) – but the linear combination is stationary or I(0).[1] Two variables might thus be drifting upwards together. Because PPP is primarily a long-run phenomenon, cointegration analysis is well suited to detect it.

The earliest and best-known cointegration technique is the residual-based method of Engle and Granger (1987). Two variables that are integrated of the same order are put into a regression, and the residuals are tested for stationarity using a unit-root test such as those described above. It is also possible to fit a regression equation that represents the long-run relationship. Because the original Engle–Granger method assesses relationships between two variables, the Johansen and Juselius (1990) multivariate cointegration technique has grown in popularity and is used in the vast majority of the studies described below. The method searches for cointegrating vectors via trace and maximum-likelihood tests, and also provides a long-run equation. Some of the studies described here apply less-common methods, however.

Cointegration analysis can be used to find evidence of relative PPP, while rejecting the stricter assumptions required to show absolute PPP. Absolute PPP depends upon satisfying the so-called 'proportionality conditions', where, in equation (2), $\alpha = 0$, $\beta = 1$ and $\gamma = -1$. Because these strict conditions are often not met, the presence of a long-run relationship among the variables (regardless of the coefficient estimates) indicates that the weaker version of PPP still holds. Because of the presence of non-negligible transport costs, as well as the fact that price indices can only measure true price levels inaccurately, it is quite possible that the assumptions required for absolute PPP are difficult to find empirically. Although many studies test for both absolute and relative PPP – often finding that only the latter holds – others immediately relax the strictest assumptions and focus on the cointegration results.

McNown and Wallace (1989) were among the first to apply cointegration analysis to LDCs, testing two versions of the PPP equation:

$$X_t = a + b\left(P_t^d - P_t^f\right) + U_t \tag{6a}$$

and

$$P_t^d = c + d\left(X_t + P_t^f\right) + V_t \tag{6b}$$

Table 1. Linear Unit-root Tests of PPP: Main Features of Reviewed Papers.

Author (year)	Countries	Methodology	Exchange rate	Variables	Time period	Results
Abumustafa (2006)	Jordan	KPSS, ADF, PP	Real bilateral with yen, DM	CPI	Quarterly: 1976–2000	PPP holds
Achy (2003)	38 middle-income countries	ADF, also ARFIMA	Real bilateral with US dollar	CPI	Monthly: 1973–1998	Mixed
Aggarwal *et al.* (2000)	7 Asian LDCs	ADF	Real bilateral with yen	CPI, PPI	Quarterly: 1974–1997	Long-run quasi-PPP with changes in mean
Akinboade and Makina (2006a, 2006b)	South Africa	KPSS, ADF, PP	Real bilateral with dollar, pound, yen, Euro	CPI	Monthly: 1978–2002	Stationary with breaks, not without
Apergis (2003)	Armenia	DF-GLS	Real bilateral with US dollar	CPI	Monthly: 1993–1996	No evidence for PPP
Bahmani-Oskooee (1995)	22 LDCs	ADF	Real effective, Nominal effective	CPI	Quarterly: 1971–1990	Fails to hold for most countries
Bahmani-Oskooee (1998)	11 Middle Eastern	KPSS, ADF	Real effective	CPI	Quarterly: 1971–1994	KPSS test shows more support for PPP than ADF
Bahmani-Oskooee and Mirzaie (2000)	20 LDCs	KPSS	Real effective		Quarterly: 1973–1997	KPSS test shows more support for PPP than ADF
Bahmani-Oskooee *et al.* (forthcoming)	113 countries, including 88 LDCs	KPSS	Real effective		Monthly: 1980–2005	Most LDCs show support for stationary

Journal of Economic Surveys (2009) Vol. 23, No. 4, pp. 617–658

Bleaney *et al.* (1999)	Argentina, Brazil, Chile, Colombia, Israel	Stochastic unit root	Real bilateral with US dollar	WPI	Monthly: 1972–1993	Mean reversion; Chile rejects unit root
Doğanlar and Ozmen (2000)	18 LDCs	ADF, PP	Real bilateral with US dollar	CPI	Monthly: 1986–1997	All non-stationary: evidence of PPP
Khoon and Mithani (2000)	Malaysia	ADF	Real bilateral with US dollar	WPI, CPI	Quarterly: 1973 or 1984 to 1997	Random walk
Lee (1999)	13 Asia Pacific	Error-correction	Real bilateral with US dollar	CPI, WPI	Monthly: 1957–1994	Little support for PPP
Payne *et al.* (2005)	Croatia	Multiple	Real effective	PPI, retail PI	Monthly: 1992–1999	Fails to find support
Tastan (2005)	Turkey	ADF, PP	Real with lira, dollar, DM, pound	CPI, PPI	Monthly: 1982–2003	Holds for dollar and pound only – holds overall

ARFIMA, autoregressive fractionally integrated moving average; PPI, producer price index; DF-GLS, Dickey–Fuller generalized least squares.

Journal of Economic Surveys (2009) Vol. 23, No. 4, pp. 617–658

where X_t is the nominal exchange rate, and b and d are supposed to equal one. Using both the CPI and the WPI as the price index, the authors use the Engle–Granger technique to study the high-inflation countries of Chile, Argentina, Israel and Brazil. Estimates of b and d are close to one, as the theory of PPP would suggest. The choice of price index affects the results, however: using the WPI, cointegration is supported in Chile, Argentina and Brazil, but with the CPI in none of the countries does cointegration receive any support. Nonetheless, assuming that WPI is a more accurate measure of the price level, PPP is shown to hold.

Liu (1992), using OLS and both residual-based methods and the Johansen procedure to analyse nine Latin American countries (including Chile, Argentina and Brazil) over a 40-year span, arrives at mixed results. Using the CPI for the price level, absolute PPP is rejected for three countries, accepted for three, and deemed to be indeterminate for the other three, including Argentina and Chile. Using WPI for six of the countries for which data were available, the results are more supportive of PPP.

The choice of stationarity test – here, the ADF and the Phillips Z_α and Z_t tests – give differing results as well. Brazil, for example, is indeterminate using the Z_α test, but rejects the null of no cointegration using the Z_t test and also shows evidence of cointegration via the ADF test. Liu finds that the Johansen cointegration procedure is more supportive of PPP, with Brazil and Chile conforming to the hypothesis using both CPI and WPI. These results appear to support the earlier work of McNown and Wallace (1989), as does the residual-based study of Conejo and Shields (1993), which finds evidence of absolute PPP only for Brazil and Mexico, out of five Latin American countries. Still, the choice of price level may affect the overall results.

Bahmani-Oskooee and Rhee (1992) focus on the choice of exchange rate, using the effective rather than the nominal exchange rate to study the Korean won. Bahmani-Oskooee (1993a) applies OLS and the Engle–Granger cointegration method to the effective exchange rates of 25 LDCs. Eighteen of these countries are analysed, four of which are shown to be cointegrated, and the estimated slope coefficients are generally significantly different from one – indicating the failure of PPP to hold for effective exchange rates. Using bilateral exchange rates instead, PPP is shown to hold for seven of 16 countries. This lack of evidence for PPP using the effective exchange rate is confirmed by Gan (1994), who rejects cointegration using the real effective exchange rates of five Asian countries via the Engle–Granger procedure.

Because LDCs are prone to specific problems such as currency controls and high inflation, analyses of these problems are key in the literature. Regarding currency controls, Bahmani-Oskooee (1993b) tests the Iranian rial's black market and official rates versus 19 currencies. Using the Engle–Granger cointegration method, he finds support for relative PPP only when the black-market rate is used, indicating the appropriateness of using this exchange rate in empirical studies.

El-Sakka and McNabb (1994) also arrive at a similar conclusion in a study of Egypt's black-market rate. Results from both the Engle–Granger and the Johansen techniques find evidence of PPP in this case. Other studies concur: Phylaktis and

Kassimatis (1994) also find support for relative PPP by finding evidence of mean reversion for the black-market exchange rates of eight Pacific Basin countries.

Mahdavi and Zhou (1994) apply the Johansen procedure to address PPP in 13 high-inflation countries. Only three countries conform to absolute PPP, and the results improve only slightly (to five countries) for the more lenient relative PPP assumption. Significantly, there is shown to be more evidence for PPP when inflation is higher, indicating that price changes are more capable of smoothing out deviations from PPP.

Also important for LDCs is economic integration – such groups as MERCOSUR and ASEAN aim to strengthen these ties among their members. PPP might thus behave differently inside a group than outside. Enders and Hurn (1994) look for 'generalized purchasing power parity' (G-PPP), where the variables among groups of countries exhibit common trends. If this is the case, then the countries are said to form an optimal currency area. The authors use the Johansen procedure to study India, Indonesia, Korea, the Philippines, Singapore and Thailand (*vis-à-vis* the USA, Japan, Germany and the UK). They find that G-PPP is shown to hold bilaterally between all six countries (except India) and the large countries, but not bilaterally between pairs of large countries, and only weakly between pairs of the Asian LDCs. Thus, these Asian countries show evidence of G-PPP with large industrial countries, but only weak evidence for this phenomenon is found for the Asian countries as a group. Kim (1995) tests for 'multicountry' PPP for the Korean won real effective exchange rate, with a model of deviations that includes such variables as interest rate differentials and the accumulated trade balance. Using the Park (1990) J-test, Kim (1995) finds that the won satisfies 'multicountry' PPP. This result contradicts Bahmani-Oskooee (1993a) and Gan (1994), who find little evidence for PPP using effective exchange rates.

Studying another single Asian country, Masih and Masih (1995) find that a more sophisticated test provides evidence of relative PPP for Taiwan, where more traditional tests had found none. Although the Engle–Granger and Johansen tests do not reject non-stationarity in the exchange rate, a semi-nonparametric test for fractional integration shows mean reversion and thus supports PPP.

Transition economies have also been an area of focus in cointegration studies. Thacker (1995) finds no support for PPP for Poland and Hungary via a residual-based test, but Bahmani-Oskooee and Barry (1997), using the Johansen procedure, find evidence of absolute PPP for Russia. Although it has been shown that the choice of cointegration test is important, perhaps Russia's higher inflation rate provides an explanation behind support for PPP only in that country.

On the other hand, Baharumshah and Ariff (1997) apply both the Engle–Granger and Johansen tests for five Asian countries and find no support for PPP, regardless of the inflation rate. Results continue to be mixed. Incorporating endogenous structural breaks that correspond to significant events within countries (such as episodes of exceptionally high inflation), Zhou (1997) examines the high-inflation countries of Brazil, Mexico, Israel and Zaire. Applying the Johansen test that accounts for these trend breaks, Zhou finds a cointegrated relationship among the variables for all four countries. Bleaney *et al.* (1999) apply a stochastic unit-root rest to a similar

set of countries and find some evidence of mean reversion and thus PPP. Tan and Baharumshah (1998) use both spectral regression and the Johansen procedure to study five ASEAN exchange rates. Both tests arrive at similar conclusions and show relative PPP for Indonesia, the Philippines and Thailand – countries with high inflation rates – but no evidence of PPP for low-inflation Singapore and Malaysia.

Regarding other high-inflation transition economies, Choudhry (1999) incorporates fractional cointegration in a study of Poland, Romania, Russia and Slovenia and arrives at mixed results. Weak support for PPP is found in the bilateral relationships between Russia and Slovenia with the USA, whereas relative (but not absolute) PPP is shown between Russia and Poland and Russia and Slovenia. Relying on the Johansen method and the Stock–Watson dynamic OLS procedure, Christev and Noorbakhsh (2000) find less evidence for PPP in Bulgaria, the Czech Republic, Hungary, Poland, Romania and Slovakia, of which Bulgaria and Romania had very high inflation. Although there are shown to exist cointegrating vectors for these exchange rates, other evidence suggests against mean reversion. Various factors might account for this, including productivity shocks, inflexible exchange rates and an abundance of non-traded goods. Barlow (2003) arrives at mixed results for Poland, the Czech Republic and Romania using the Johansen technique. Relative PPP is only shown to hold between the two more advanced transition economies of Poland and the Czech Republic, but not between the other pairs of countries or for bilateral pairs with the USA. Boršič and Bekö (2006) find little support for PPP for Slovenia and Hungary. This variance in results again highlights arguments in favour of using more sophisticated econometric techniques, as the traditional tests tend to reject PPP for transition economies.

Nonetheless, the Johansen procedure is often applied to the question of PPP in a wide range of countries. Studies include Kahn and Parikh (1998), who finds support for absolute PPP for the South African rand with the US dollar, and evidence for relative PPP with the British pound; Islam and Ahmed (1999), who find stronger support for relative PPP in Korea using that test over the Engle–Granger method; Salehizadeh and Taylor (1999), who find evidence for cointegration for 14 out of 27 emerging economies; Sanchez-Fung (1999), who demonstrates relative PPP for the black-market exchange rate of the Dominican Republic; and Yazgan (2003), who also finds support for absolute PPP in Turkey where the previous study of Telatar and Kazdagli (1998) had not. Although the Johansen test is popular, it does not definitively solve the puzzle.

Asian countries are among the most popular subjects of study in the PPP literature, often due to their strong trading relationships with Japan – although various studies often arrive at conflicting results. Wang (2000) finds no PPP vector for seven Asian nations using the Johansen method; Yunus (2000) demonstrates evidence for relative PPP for five Asian countries; Bhatti (2000) studies eight bilateral Pakistani rates (versus India, Indonesia, Japan, Korea, the Philippines, Singapore, Sri Lanka and Thailand). The Engle–Granger and Phillips–Oularis tests show support for absolute PPP in five of the eight pairs; the Johansen test shows none. Finally, although Bahmani-Oskooee and Goswami (2005b) demonstrate that whereas the black-market exchange rates of eight Asian LDCs are cointegrated with

price levels, the fact that the price levels are shown not to be exogenous indicates that PPP must be rejected. Most recently, Baharumshah *et al.* (2008) apply the autoregressive distributed lag cointegration method to study relative PPP in six Asian countries versus the USA and Japan. PPP appears to hold better after the Asian crisis; clearly this event caused a structural break.

Tests that allow for structural breaks, especially corresponding to the 1997 crisis, have generally helped uncover more evidence of PPP for Asian countries. Zurbruegg and Allsopp (2004) use the newer Johansen *et al.* (2000) test for seven Asian countries; five show support for absolute PPP if endogenous structural breaks (corresponding to the Asian crisis) are allowed. Choudhry (2005) suggests evidence for an optimum currency area in a study of five Asian nations, incorporating a break in June 1997, and finding support for G-PPP after the break.

Africa also has received special attention in the literature, even though data limitations can hinder the analysis. Here, both traditional and more advanced techniques have generally found evidence of PPP. Kargbo (2003a) applies the Johansen method to the annual black-market exchange rates of 30 countries; support for relative PPP is shown, as most relationships have at least one cointegrating vector. Using food prices as the price index (because of agriculture's obvious importance to Africa's economies), Kargbo (2003b) finds 'overwhelming' support for relative PPP in 25 countries. Kargbo (2004) arrives at similar conclusion in a study of the annual official rates of 35 African nations, finding support for PPP for almost all countries. Holmes and Wang (2005) look for 'asymmetric PPP', which depends on whether the deviation from PPP is positive or negative. Because rigidities such as downward movement in prices make exchange-rate adjustment slow at times, relative PPP may hold in a slightly altered form. The authors examine quarterly observations for 10 African nations; long-run PPP holds for eight of these. Kargbo (2006) finds strong support for PPP in the black-market exchange rates of 40 African countries. These studies show the most consistent support for PPP in all of the LDC literature.

All in all, cointegration analysis has been able to test for long-run PPP for a vast range of countries. Although Asian nations have been especially popular test subjects in the literature, Latin America, Russia and Eastern Europe and Africa have also been examined in detail. Results have been mixed, with PPP often being supported and rejected for the same countries in different studies. Although the Johansen test is popular, a review of the literature suggests that tests that assess structural breaks or asymmetries might be more supportive of PPP. Few of these studies, however, have sought to explain the deviations. Panel studies have been more effective in this respect. Table 2 summarizes all the studies reviewed in this section by listing, again, their main features.

3.3 *Panel Tests of PPP*

Most studies have evaluated PPP in terms of single equations for individual countries, but a number have used panel approaches. Oftentimes, LDCs are included alongside developed countries as part of a large panel, and occasional analyses

Table 2. Linear Cointegration Tests of PPP: Main Features of Reviewed Papers.

Author (year)	Countries	Methodology	Exchange rate	Variables	Time period	Results
Baharumshah and Ariff (1997)	5 South Asian	Engle–Granger, Johansen	Nominal bilateral with US dollar	CPI	Quarterly: 1974–1993	No cointegrating vector – PPP does not hold
Baharumshah *et al.* (2008)	6 Asian	Autoregressive distributed lag	Nominal bilateral with dollar, yen		Monthly: 1976–2002	Evidence for PPP only after Asian crisis; short half-life
Bahmani-Oskooee (1993a)	25 LDCs	Engle–Granger	Bilateral with US dollar	CPI	Quarterly: 1973–1988	Holds for 7 of 16 with bilateral, but fails with effective rates
Bahmani-Oskooee (1993b)	Iran	Engle–Granger	Black market with 19 currencies	CPI	Quarterly: 1973–1986	Support for PPP only when black-market rate is used
Bahmani-Oskooee and Rhee (1992)	Korea	Engle–Granger	Effective	CPI	Monthly: 1980–1989	Rejects PPP
Bahmani-Oskooee and Barry (1997)	Russia	Johansen	Nominal bilateral with US dollar	CPI	Monthly: 1991–1995	Johansen gives unit root, but ADF does not
Bahmani-Oskooee and Goswami (2005a)	31 LDCs	Johansen	Black market, Official		Annual: 1955–1995	Cointegrated (for 15/22)
Bahmani-Oskooee and Goswami (2005b)	8 Asian	Johansen	Black market		Monthly: 1958–1989	Rejects PPP due to lack of exogeneity

Journal of Economic Surveys (2009) Vol. 23, No. 4, pp. 617–658

Barlow (2003)	Poland, Czech Republic, Romania	Johansen	Nominal, average of DM, dollar	CPI	Monthly: 1994–2003	Poland, Czech Republic: not stationary against DCs or Romania, but stationary against each other
Bhatti (2000)	Pakistan	Engle–Granger, Phillips–Oularis, Johansen	Nominal bilateral with India, Indonesia, Japan, Philippines, Singapore, Korea, Sri Lanka	WPI	Quarterly: 1981–1998	PPP: Korea, Singapore, Philippines, Indonesia, Thailand with Johansen
Borsic and Beko (2006)	Slovenia and Hungary	Johansen	With Austria, Germany, France, Italy	CPI	Monthly: 1992–2001	No firm evidence for PPP
Choudhry (1999)	Poland, Romania, Russia, Slovenia	Fractional, Harris–Inder	Nominal bilateral with US dollar	CPI	Monthly: 1991–1997	Weak for Russia and Slovenia with USA; relative PPP for Russia–Poland, Russia–Slovenia; no absolute PPP

Journal of Economic Surveys (2009) Vol. 23, No. 4, pp. 617–658

Table 2. *Continued.*

Author (year)	Countries	Methodology	Exchange rate	Variables	Time period	Results
Choudhry (2005)	Thailand, Malaysia, Indonesia, the Philippines, South Korea	Johansen	Real with yen, dollar, also baht	CPI	Monthly: 1990–2004	Generalized PPP after Asian crisis, but not before
Christev and Noorbakhsh (2000)	Six Central and East European	Stock–Watson, Johansen	Bilateral with DM, ECU, US dollar	CPI	Monthly: 1990–1998	Rejects PPP
Conejo and Shields (1993)	Brazil, Colombia, Costa Rica, Mexico, Venezuela	Engle–Granger	Nominal bilateral with US dollar	WPI, CPI	Annual: 1941–1990	Relative PPP only for Brazil and Mexico
Enders and Hurn (1994)	India, Indonesia, Philippines, Korea, Singapore, Thailand	Johansen	Real with Germany, UK, USA; Japan base	WPI	Monthly: 1973–1989	G-PPP holds between Asian countries and industrial partners; only weak evidence that it holds in Asia as a group
Gan (1994)	5 Asian	Engle–Granger	Nominal effective	WPI	Monthly: 1974–1987 or 8	PPP fails
Holmes and Wang (2006)	9 Asian	Engle–Granger	Nominal pairwise	CPI, PPI	Monthly: varies	Weak? Maybe only for large devaluations
Islam and Ahmed (1999)	Korea	Engle–Granger, Johansen	Nominal bilateral with US dollar	CPI	Quarterly: 1971–1996	Supports PPP

Journal of Economic Surveys (2009) Vol. 23, No. 4, pp. 617–658

Kahn and Parikh (1998)	South Africa	Johansen	Nominal bilateral with pound, US dollar	CPI, PPI	Monthly: 1975–1994	Strong PPP with dollar, weak PPP with pound
Kargbo (2003a)	30 African countries	Johansen	Black market	CPI	Annual: 1960–1997	Supports PPP
Kargbo (2003b)	25 African countries	Johansen	Nominal bilateral with US dollar	Food prices	Annual: 1958–1997	'Overwhelming' support for PPP
Kargbo (2004)	35 African countries	Johansen	Nom	CPI	Annual: 1958–2002	Supports PPP
Kargbo (2006)	40 African countries	Johansen	Nominal bilateral with US dollar	GDP deflator	Annual: 1958–2003	Supports PPP
Kim (1995)	Korea	Park	Nominal bilateral with US dollar	PPI	Monthly: 1980–1993	'Multicountry' PPP
Liu (1992)	9 Latin American	Johansen	Nominal bilateral with US dollar	CPI and WPI	Quarterly: varies up to 1989	Supports PPP
Lo and Wong (2006)	63 countries	FMOLS, Panel	Nominal bilateral with US dollar	GDP, money supply, CPI	Annual: 1973–1997	PPP increases with openness
Mahdavi and Zhou (1994)	Argentina, Brazil, Greece, Israel, Nigeria, Mexico, Peru, Portugal, South Africa, Turkey, Uruguay, Yugoslavia, Zaire	Johansen	Nominal bilateral with US dollar	WPI for most, also CPI		Absolute: Argentina, South Africa, Uruguay Relative: Brazil, Israel, Mexico, Peru, Yugoslavia

Journal of Economic Surveys (2009) Vol. 23, No. 4, pp. 617–658

Table 2. *Continued.*

Author (year)	Countries	Methodology	Exchange rate	Variables	Time period	Results
Masih and Masih (1995)	Taiwan	Fractional Engle–Granger, Johansen	Nominal bilateral with US dollar	CPI	Monthly: 1981–1992	Mean reversion
McNown and Wallace (1989)	Argentina, Brazil, Chile, Israel	Engle–Granger	Nominal bilateral with US dollar	CPI, WPI	Monthly, varies	Supports PPP
Phylaktis and Kassimatis (1994)	8 Pacific Basin countries	Engle–Granger, Johansen	Black market Nominal bilateral with US dollar	CPI, WPI	Monthly: 1974–1987	Mean reverting, 1.5-year half life
El-Sakka and McNabb (1994)	Egypt	Engle–Granger, Johansen	Black market	Unspecified	Quarterly: 1958–1987	Evidence for relative PPP
Salehizadeh and Taylor (1999)	27 emerging and LDCs	Johansen	Nominal bilateral with US dollar	CPI	Monthly: 1975–1997	Mixed – 14 countries stationary, but not symmetric
Sanchez-Fung (1999)	Dominican Republic	Engle–Granger, Johansen	Black market with dollar	WPI	Quarterly: 1970–1999	Relative PPP holds
Tan and Baharumshah (1998)	5 Asian	Johansen	Nominal bilateral with US dollar	CPI	Quarterly: 1976–1995	Relative PPP holds for Indonesia, Philippines, Thailand (high inflation), but not Singapore or Malaysia

Journal of Economic Surveys (2009) Vol. 23, No. 4, pp. 617–658

Telatar and Kazdagli (1998)	Turkey	Residual	Nominal bilateral with mark, lira, franc, pound	CPI	Monthly: 1980–1993	PPP does not hold
Thacker (1995)	Poland and Hungary	PP	Nominal bilateral with US dollar, pound, DM	CPI and WPI	Monthly: 1991–1993	Unit root: PPP fails to hold
Wang (2000)	7 Asian	Johansen	Nominal bilateral with other Asian currencies	CPI	Monthly: 1973–1996	No cointegrating vector: PPP fails
Yazgan (2003)	Turkey	Johansen	Nominal bilateral with mark, dollar, lira	CPI	Quarterly: 1982–2001	PPP does hold
Yunus (2000)	5 South Asian	Johansen	Nominal bilateral pairwise	CPI	Monthly	Weak, not strong, PPP
Zhou (1997)	4 high-inflation countries: Brazil, Mexico, Israel, Zaire	Johansen with breaks	Nominal bilateral with USA	CPI	Varies	Cointegration – PPP holds
Zurbruegg and Allsopp (2004)	East Asian	Johansen	Nominal bilateral	CPI	Monthly: 1990–2002	Supports PPP

FMOLS, fully modified OLS.

Journal of Economic Surveys (2009) Vol. 23, No. 4, pp. 617–658

have focused specifically on LDCs. Transition economies, however, have not been studied as much using these techniques.

Panel approaches help solve the problem, common to LDCs and transition economies, of short data sets. They are also often used to control for cross-sectional correlation, although it has been pointed out that this correlation is often simply ignored rather than actually controlled for. The assumption of no cross-sectional correlation has been relaxed in so-called 'second-generation' panel tests. Harris *et al.* (2005), for example, use this type of panel stationarity test and find no evidence of PPP in a sample of 17 developed countries.

It is important to note that relatively new methods such as these are generally applied first to developed countries before being used to address issues in LDCs or transition economies. As a result, few studies employ these techniques to the countries described in this review. Nonetheless, faced with a prevalence of annual data from LDCs and a short transition period for post-communist countries, even first-generation panels are useful in providing a sufficient number of observations for estimation. Panel tests of transition economies are surprisingly rare, however.

The two main first-generation techniques found in the literature are that of Im, Pesaran and Shin (IPS; Im *et al.*, 2003), and that of Levin, Lin and Chiu (LLC). The IPS '*t*-bar' test is a panel unit-root test that does not give a coefficient with which to determine speed of convergence; the LLC test does allow this to be measured. An additional drawback of the IPS test is the fact that it gives in effect an average *t*-ratio without providing any information regarding the stationarity of the individual series in the panel. Surprisingly underused is the seemingly unrelated regressions ADF test, which has been found by Breuer *et al.* (2001) to be more powerful than these other tests, more easily discerning between I(1) and I(0) variables.

Panel unit-root tests, like their linear counterparts, address the presence or absence of stationarity in the real exchange rate, with the main difference being that it is done for groups or subgroups of countries. Frankel and Rose (1996) examine 150 countries, without a specific focus on LDCs, and find evidence of mean reversion. O'Connell (1998) eliminates cross-sectional dependence with a panel of 64 countries that is further broken down to include 13 Asian, 13 South American and 13 African LDCs. Applying a GLS panel unit-root test to the real exchange rate, he rejects the null of the random walk for all countries, thus finding support for PPP.

As was the case with linear unit-root tests, the choice of price index often influences the results. Wu and Chen (1999), studying eight Pacific Basin countries via both the IPS and the Maddala and Wu tests, find support for PPP when the real exchange rate is constructed using the CPI, but not the WPI. On the other hand, panel unit-root tests appear to avoid the 'power problem' of linear unit-root tests – panel tests often find support for PPP where linear approaches do not. Holmes (2000), analysing 27 African countries with the IPS *t*-bar test, rejects PPP when individual unit-root tests are performed, but finds support for PPP in all countries when the panel test is performed. In line with most of the previous literature, he finds that high-inflation countries show stronger evidence of PPP than do lower-inflation countries. Further support for PPP in Africa is found by

Holmes (2001b), who rejects the null of non-stationarity for a panel of 30 African countries.

Support for PPP has generally been mixed using panel unit-root tests. Chiu (2002) uses a Lagrange multiplier test and a KPSS-based test to find support for PPP in 45 economies. Alba and Park (2003) apply the LLC test on a panel of 80 countries, which includes 65 LDCs. They account for shifts in the PPP relationship by studying moving 10-year periods, and group LDCs according to such factors as their degree of openness and the inflation rate. They find only weak support for PPP in the various groups, but their work draws attention to reasons why PPP might fail. Wu *et al.* (2004) also arrive at mixed results applying the IPS test for eight Asian economies, including Japan. Monthly data are shown to be stationary when a change in the mean is allowed, but quarterly data fail to reject the null of non-stationarity for three of the countries. On the other hand, Hassanain (2004a) finds support for PPP in 10 Arab countries, even when various base currencies are used. He attributes this to economic openness and low exchange-rate volatility. More recently, Baharumshah *et al.* (2007) also finds that the choice of base currency (dollar or yen) does not matter for six East Asian real exchange rates, which show evidence of PPP after the Asian crisis (but not before).

Various factors have been proposed to explain the varying results generally found in panel PPP studies. Wagner (2005) discusses the problems associated with first-generation panel unit-root tests before studying a panel of 57 countries worldwide, including 11 Central and East European countries. He shows that, using a second-generation test, no support for PPP can be found for any of the sub-panels in the study.

Alba and Papell (2007) find that it is not a simple yes-or-no question of whether PPP holds or not, but rather a spectrum in which some countries can adhere more strongly than others for various reasons. Applying the LLC test to a panel of 84 countries, they conclude that PPP holds for Latin America and Europe, but not Asian or African countries. They attribute differences in PPP to geographic and macroeconomic factors. Solakoglu (2006), while finding that PPP holds for his 12-year panel of 21 Eastern European countries and former Soviet republics, studies the effects of increased openness and reform on this process. He concludes that more open economies demonstrate a faster speed of convergence to equilibrium. On the other hand, methodological approaches may offer a solution. Zhang and Lowinger (2006), using the LLC test on 10 large LDCs, finds support for PPP only if a time trend is allowed. Hooi Hooi and Smyth (2007), incorporating up to two structural breaks into their analysis, find that univariate unit-root tests confirm PPP for 10 of 15 Asian exchange rates. Lagrange multiplier panel unit-root tests show evidence of long-run PPP for the sample. The results do vary by test type, however. In short, whereas panel approaches (especially when they are modified) solve some of the problems faced by linear tests, these tests still provide mixed results that need to be addressed.

Fewer studies have used panel cointegration methods to evaluate PPP in less developed countries. Nagayasu (2002) applies the Pedroni (2001) technique to annual observations for 17 African countries, and finds support for PPP. Basher and

Mohsin (2004) reject PPP, using the same method for 10 Asian economies. Sideris (2006) arrives at mixed results in a study of 17 transition economies in Europe. The linear Johansen test rejects PPP for all countries, but a panel technique finds some, albeit weak, evidence for PPP in some cases. Lo and Wong (2006), in a panel of 63 countries, find that support for PPP increases with openness. Drine and Rault (2007) examine a sample of 80 countries, including LDCs and transition economies, and find that for these two groups PPP does not seem to hold. Cerrato and Sarantis (2007) apply both unit-root and cointegration tests to a panel of 34 emerging markets and conclude that black-market exchange rates do not exhibit mean-reverting behaviour. Cointegration tests tend to confirm PPP, however, although the coefficients do not conform to the (overly) strict proportionality conditions required for absolute PPP.

The panel results discussed here, like their time-series counterparts, are mixed. They identify economic openness as a key factor in the presence of a PPP relationship. Although panels often produce varied results, they allow the identification of specific reasons why this is the case. The main features of studies reviewed in this section are provided in Table 3.

3.4 *Nonlinear Tests of PPP*

Even with the more advanced linear methods described above, firm support for PPP has remained elusive. It is possible that exchange rates behave nonlinearly, due to such factors as transactions costs, which create a threshold below which prices are inflexible, and government policy, which is often more active once exchange rates move farther away from their targets. Also important is the distinction between upward and downward deviations from PPP. Because prices have less of a tendency to move downwards, the exchange rate might have to do more of the adjusting, and movements might thus not be symmetric between the two directions. As a result, nonlinear methods have been growing in popularity as a way to capture mean reversion, as linear methods would be unable to do so.

Also popular are threshold methods, which generally incorporate a variable that equals zero below a certain value and one thereafter. Tests of PPP, rather than use a discrete threshold, generally incorporate a band in which a variable behaves as if it has a unit root, but can be mean reverting outside. An early study that applied nonlinear methods to developed countries was performed by M.P. Taylor and Peel (2000), who find evidence of nonlinear mean reversion for the US dollar versus the pound and the yen.

Nonlinear methods can be particularly useful in the study of LDCs and transition economies. These countries face both external and internal shocks that are not common for developed countries, such as periods of high inflation, terms of trade and climate shocks and massive depreciation or devaluation of the exchange rate. Thus, as these relatively new methods begin to be applied outside the realm of the developed world, they may be able to be especially appropriate for these countries.

Nonlinear methods are more complicated than linear ones, but might be necessary if a true PPP relationship is to be identified. Nonlinear tests for PPP tend to focus

Table 3. Panel Tests of PPP: Main Features of Reviewed Papers.

Author (year)	Countries	Methodology	Exchange rate	Variables	Time period	Results
Alba and Park (2003)	80 total; 65 LDCs	LLC (stationarity)	Real with US dollar	CPI	Annual: moving 10-year periods	Weak support; various groups (based on openness, inflation etc.)
Alba and Papell (2007)	84 countries	LLC, IPS (stationarity)	Real with US dollar	CPI	Monthly: 1976–2002	PPP holds for European and Latin American panels, not Africa or Asia
Baharumshah *et al.* (2007)	6 East Asian	IPS, LLC, Breitung	Real with dollar and yen		Monthly: 1973–2002	PPP holds best post-crisis; invariant to choice of base currency
Basher and Mohsin (2004)	10 Asian countries	LLC, IPS	Real bilateral with US dollar	CPI	Monthly, quarterly: 1980–1999	No PPP
Cerrato and Sarantis (2007)	34 countries	Various unit-root and cointegration tests	Black market with dollar	CPI	Monthly: 1973–1998	Unit-root tests reject PPP; cointegration (but not stricter assumptions) confirms PPP
Chiu (2002)	45 countries	Multiple	Real bilateral with US dollar	CPI	M, Q, A: 1980–2004	Supports PPP

Journal of Economic Surveys (2009) Vol. 23, No. 4, pp. 617–658

Table 3. *Continued.*

Author (year)	Countries	Methodology	Exchange rate	Variables	Time period	Results
Drine and Rault (2007)	80 countries	Pedroni (cointegration)	Effective	CPI	Q, A: 1970–1998	No PPP in many LDCs and transition economies
Frankel and Rose (1996)	150 countries	DF, OLS	Real bilateral with US dollar	CPI	Annual: 1948–1992	Half life of 4 years
Hassanain (2004a)	10 Arab countries	IPS	Real bilateral with 9 base currencies	CPI	Quarterly: 1974–1999 Annual: 1974–1998	Stationary
Hassanain (2004b)	24 African countries	ADF, instrumental variable	Real bilateral with US dollar	CPI	Quarterly: 1974–1979	Support for entire panel, as well as non-CFA subpanel; not for CFA member countries
Holmes (2000)	27 African countries	IPS	Real bilateral with US dollar	CPI	Quarterly: 1974–1979	Generally confirmed
Holmes (2001b)	30 LDCs	IPS, also SUR	Real with US dollar	CPI	Quarterly: 1973–1999	Rejects PPP
Hooi Hooi and Smyth (2007)	15 Asian	LM unit root	Real bilateral with US dollar		Monthly: varies – 2005	Mixed results: varies by test
Nagayasu (2002)	17 African countries	ADF, IPS	Parallel market rates	CPI	Annual: 1981–1994	Weak, not strong, PPP
O'Connell (1998)	64 countries	GLS	Real	CPI	Quarterly: 1973–1995	Evidence for PPP, but not for Africa

Journal of Economic Surveys (2009) Vol. 23, No. 4, pp. 617–658

Sideris (2006)	17 European transition economies	Johansen, Larsson	Real bilateral with US dollar	CPI	Monthly: 1990 or 1995–2004	Not symmetric – no PPP
Solakoglu (2006)	21 transition economies	Levin–Lin, IPS	Real bilateral	CPI	Annual: 1992–2003	PPP holds
Wagner (2005)	11–57 countries; Euro area	'Second-generation': Bai and Ng	Real effective		Monthly: varies	PPP weak at best with new methods
Wu and Chen (1999)	8 Pacific Basin countries	IPS	Real bilateral with US dollar	WPI, CPI	Monthly: 1980–1996	PPP fails
Wu *et al.* (2004)	8 Pacific Basin	IPS	Real bilateral with US dollar	CPI	Monthly: 1980–2000	Results mixed
Zhang and Lowinger (2006)	10 LDCs	LLC	Based on dollar	CPI	Quarterly: 1970–2004	PPP might hold

SUR, seemingly unrelated regression.

Journal of Economic Surveys (2009) Vol. 23, No. 4, pp. 617–658

on whether or not the real exchange rate is stationary, versus the alternative of the variable following a nonlinear autoregressive process. Nonlinear methods are explained in great detail by Van Dijk *et al.* (2002).

Other linear procedures, such as estimating functional forms (cointegration) or panel approaches, have nonlinear counterparts that have found more limited application to the study of PPP. Sarno (2000), for example, incorporates prices into a smooth transition regression (STR) model, but focuses on autoregressive methods. Hassanain (2004b) employs a nonlinear panel instrumental variable unit-root test to quarterly and annual African data, and finds strong support for PPP for those countries that are not part of the CFA currency bloc. Enders and Chumrusphonlert (2004) apply a threshold cointegration technique to a study of eight Pacific nations and conclude that PPP holds with asymmetric adjustment regarding upward or downward deviations from PPP. Most nonlinear studies, however, focus on stationarity and autoregression.

In these types of nonlinear study, the variables in question must first be tested for linearity. Recent analyses have pointed to possible nonlinearity as a possible explanation for the failure of PPP. Holmes (2002), for example, tests linearity for 13 Latin American exchange rates by testing the equation

$$\upsilon_t = \beta_0 + \beta_1' x_t + \beta_2' x_t e_{t-d} + \beta_3' x_t e_{t-d}^2 + \beta_4' x_t e_{t-d}^3 + w_t \tag{7}$$

across ranges of d. The null hypothesis is that $\beta_2^{'} = \beta_3^{'} = \beta_4^{'} = 0$, which would leave a linear equation. Although the ADF test had found many of the exchange rates to be non-stationary, linearity is rejected for seven of the countries at the 10% level. Holmes then goes on to model the appropriate autoregressive processes.

More recently, the Kapetanios, Shin and Snell (2003) KSS test, which is based on the smooth transition autoregressive (STAR) methodology and is considered a nonlinear version of the linear ADF test, has been used to test for nonlinear stationarity. The test is based on the following nonlinear equation with the null hypothesis $\theta = 0$ (no nonlinearity) versus $\theta > 0$:

$$\Delta y_t = \gamma y_{t-1}\left[1 - \exp\left(-\theta y_{t-1}^2\right)\right] + \varepsilon_{t-1} \tag{8a}$$

Because the parameter θ is unknown, in reality the KSS test is of the approximation

$$\Delta y_t = \sum_{j=1}^{p} \rho_J y_{T-1} + \delta y_{t-1}^3 + \varepsilon \tag{8b}$$

with the null hypothesis $\delta = 0$ and the alternative $\delta > 0$. If the null is rejected, then the variable is said to be nonlinear stationary.

If a variable is found to have a nonlinear unit root, thus seeming to reject PPP, the next step is to determine whether this 'breakdown' might be caused by some sort of structural change within the data. Threshold autoregressive (TAR) methods, first introduced by Tong and Lim (1980), allow for a regime shift. A so-called 'band-TAR', which allows for unit-root behaviour only within a certain range, is able to capture a smooth (and often asymmetric) adjustment towards equilibrium. There is still debate, however, whether this is the most appropriate nonlinear technique to use when

testing PPP. Taylor *et al.* (2001), for example, argue that this approach is actually inappropriate due to the difficulty inherent in aggregating individual thresholds.

TARs have still found some application towards PPP. Alba and Park (2005) note that the ADF fails to reject the unit root for Turkey, but that the TAR shows evidence of nonlinear mean reversion. Leon and Najarian (2005) apply a time-varying TAR, as well as an STR and Markov-switching models, to the real effective exchange rates of 26 countries, including Asia and Latin America. They find that the evidence for a unit root in the real effective exchange rate (REER) is not robust, and that there is evidence of mean reversion, which supports PPP. Asymmetries are evident for the various groups of countries: LDCs respond more slowly to over-appreciations and over-depreciations than do industrialized countries, but Asian nations respond more strongly to over-appreciations. Li (2007) also uses a Markov-switching model, comparing three high-volatility LDCs to three developed countries.

Variants of the STAR methodology, which was brought to the fore by Granger and Terasvirta (1993), appear to be the most popular nonlinear approach for testing PPP. One extension, the exponential STAR (ESTAR), is modelled as follows:

$$\Delta q_t = b_0 + r' q_{t-1} + \sum_{j=1}^{n} b_j \Delta q_{t-j} + \left(\beta_0 + p' q_{t-1} + \sum_{j=1}^{n} \beta_j \Delta q_{t-j} \right) \times \left[1 - \exp\left\{ -\theta (q_{t-d} - c)^2 \right\} \right] + \varepsilon_t \tag{9}$$

The right-hand side of equation (9), known as the 'transition function', is clearly dependent upon q's distance from c. The further q is away from its mean, the larger this component becomes, and thus q moves in a nonlinear fashion.

This type of nonlinear approach has been able to uncover evidence of PPP that conventional tests had been unable to demonstrate. Sarno (2000), for example, extends the work of Bahmani-Oskooee (1998) by using an ESTAR model in addition to the exponential STR (ESTR). A test of restrictions determines whether the ESTR or ESTAR is appropriate for each country. Here, changes in the real exchange rate q_t are modelled not only as a linear function of the changes' lagged values, but also with an exponential term that captures nonlinearities. The author estimates the appropriate ESTR or ESTAR model through nonlinear least squares and finds nonlinear reversion to equilibrium for all countries. In other words, more support for the PPP relationship is shown here when a nonlinear technique is used rather than a linear one.

Although there have been definite advantages to using nonlinear versus linear methods, the choice of a specific nonlinear technique, as well as plotting the variables' time paths, requires some effort. Holmes (2002), for example, after determining that his Latin American exchange rates behave nonlinearly, proceeds to choose between using logistic and exponential STAR (LSTAR and ESTAR) techniques. These tests show that the LSTAR model is appropriate for all countries except Costa Rica (which is estimated with an ESTAR model instead). Holmes also plots the transition function for those seven countries, which shows the nonlinear component of the model over various values of the exchange rate. The transition is relatively

smooth for Uruguay, for example, but is more S-shaped for Venezuela, indicating a sharper transition. But these techniques are just two of the myriad possibilities.

In the past few years, the number of studies using variations of the STAR framework has exploded. Smallwood (2005) models the rates of 20 countries, including Argentina, Brazil, Korea and Mexico, with a long-memory fractionally integrated STAR framework that also incorporates a test for nonlinearity. Paya and Peel (2005) test an ESTAR model on the high-inflation countries of Argentina, Brazil, Israel and Colombia, and find that their results fit the model. Baharumshah and Liew (2006) demonstrate stronger nonlinear mean reversion for six East Asian economies compared to other models using a STAR methodology. Holmes and Wang (2006) conclude that deviations behave asymmetrically for nine Asian countries, including Japan.

Nonetheless, nonlinear stationarity tests have remained popular in studies of PPP. Liew *et al.* (2004) test for stationarity in 11 Asian real exchange rates using the KSS test. The authors reject the unit root for eight of the 11 countries, thus supporting PPP in most cases. Chortareas and Kapetanios (2004) arrive at mixed results: for the black-market real exchange rates of 35 LDCs and emerging market economies, the nonlinear KSS method rejects stationarity for 19 of them. This method thus outperforms the linear ADF test, which rejected stationarity for 30 of the 35 rates. Liew *et al.* (2005) apply an LM test to evaluate the linearity of the Malaysian ringgit, and show that it is indeed nonlinear. They then apply the KSS test, and find that the ringgit rate is non-stationary.

Most recently, Cerrato and Sarantis (2006) examine the monthly black-market rates of a panel of 35 LDCs. Where the ADF test fails, the Sollis *et al.* (2002) nonlinear unit-root test rejects the null of non-stationarity for 19 of the 35 countries at the 10% level, and the KSS test also rejects the unit root for 14 countries. Results from the STAR procedure indicate that these rates experience strong, but asymmetric, mean reversion. Chowdhury (2007) finds evidence of symmetric PPP for Bangladesh's bilateral exchange rate versus major economies using a STAR process. Bahmani-Oskooee and Kandil (2007) find that, whereas the ADF test tends to reject PPP for the majority of their 14 Middle Eastern and North African real effective exchange rates, newer tests point towards nonlinear stationarity for eight of them.

Nonlinear procedures also outperform linear ones for Bahmani-Oskooee and Tanku (2007), who apply the KSS test to the black-market and official rates of 24 LDCs. For the official rates, the ADF rejects the null of stationarity in only three cases, but the KSS test shows that 11 are stationary. Three black-market rates are also shown to be linear and stationary, but 13 are nonlinear and stationary. Thus, this study arrives at two key results: first, the KSS test finds more support for PPP than does the linear ADF test, and second, black-market rates are (slightly) more supportive of PPP than are official rates.

Although most studies that apply nonlinear approaches find stronger support for PPP than do linear tests, one interesting result is that these new techniques have shown weaker evidence for PPP in Africa. Whereas the studies of Holmes (2000, 2001b), Nagayasu (2002), Kargbo (2003a, 2003b, 2004, 2006) and Hassanain

(2004b) all showed strong support for PPP, Chang *et al.* (2006) find that PPP holds for only six of the 22 African nations they study with a dynamic nonlinear unit-root test. Using the KSS test, Bahmani-Oskooee and Gelan (2006b) also arrive at mixed results: of 21 African real effective exchange rates, 11 are stationary, thus supporting PPP for only half of the countries. Anoruo *et al.* (2006), on the other hand, find evidence for nonlinear stationarity (for the real rates) for most of the 13 African countries in their study.

In one of the relatively few studies that incorporates post-communist economies rather than focusing entirely on LDCs, Bahmani-Oskooee *et al.* (2008) examine the monthly real effective exchange rates of 88 countries. The authors find that for 12 countries a linear method is appropriate, because the ADF test shows that they behave linearly. For those that behave nonlinearly, a further 19 show support for PPP via the KSS test. Table 4 summarizes the main features of the studies reviewed in this section. In general, whereas nonlinear tests have uncovered more evidence of PPP, they still arrive at mixed results that need to be explained.

3.5 *Reasons Behind the Breakdown of PPP*

Where PPP fails, it is important to isolate the reasons why this might be the case. Some authors have focused on the choice of price level as the culprit, attempting to solve the puzzle through disaggregation. Jenkins (1997), for example, disaggregates price data into a number of sectors and finds that distance plays an important role in PPP within the USA and Canada. Others have looked at the wedge that transportation costs and trade barriers place between prices. Examples include Alessandria and Kaboski (2004, 2007) who examine violations of the law of one price through such trade policies as pricing to market and trade discrimination.

Other studies look at country characteristics. Alba and Papell (2007), for example, examine such factors as openness, distance, growth, inflation and exchange-rate risk to determine why PPP holds (versus the US dollar) for some countries better than for others. They find that nations with closer proximity to the USA (both geographically and in terms of economic growth), lower rates of inflation, less exchange-rate volatility and increased openness might show stronger evidence of PPP. Bahmani-Oskooee *et al.* (2008) also focus on country characteristics to determine why some of the 88 countries in their sample follow PPP but others do not. Such factors as increased economic openness and membership in a trade bloc are determined not to be important factors, but a high inflation rate or a flexible exchange-rate regime tend to result in a higher degree of mean reversion after a shock. Evidence of the above-mentioned 'productivity bias' is uncovered for 13 countries, but this effect is not pronounced in transition economies, where it might be expected after having suffered productivity shocks.

The Balassa–Samuelson hypothesis is still being investigated as a key cause of the breakdown in PPP. Drine and Rault (2005), for example, apply panel cointegration techniques to a sample of 12 OECD countries in an attempt to find new evidence with a new methodology. Other studies, mentioned above, propose alternative explanations for the breakdown of PPP. These include corruption (Bahmani-Oskooee

Table 4. Nonlinear Tests of PPP: Main Features of Reviewed Papers.

Author (year)	Countries	Methodology	Exchange rate	Variables	Time period	Key results
Alba and Park (2005)	Turkey	Bootstrap, threshold, unit root	Real bilateral with dollar	CPI	Monthly: 1973–2002	Mean reversion depends on threshold regime
Anoruo *et al.* (2006)	13 African	KSS	Real, nominal bilateral with dollar		Quarterly: 1972–2002	Evidence of nonlinear stationarity for most countries
Baharumshah and Liew (2006)	6 East Asian	STAR	Real bilateral with yen	CPI	Quarterly: 1980–2003	Mean reverting (stationarity)
Bahmani-Oskooee and Gelan (2006b)	21 African	KSS	Real effective		Quarterly: 1971–2004	Supports PPP in 11 countries
Bahmani-Oskooee and Tanku (2007)	24 LDCs	KSS	Real black market Official	CPI		ADF only rejects non-stationary for 3; KSS shows more support than linear tests: black-market rates show 11 stationary, 13 with official rates
Bahmani-Oskooee and Kandil (2007)	14 MENA	KSS	Real effective		Annual: 1970–2004	Nonlinear stationarity for 8/14

Journal of Economic Surveys (2009) Vol. 23, No. 4, pp. 617–658

Bahmani-Oskooee *et al.* (2008)	88 LDCs and transition economies	KSS	Real effective		Monthly: 1980–2005	12 show a linear process; 19 show PPP with non-stationary test
Cerrato and Sarantis (2006)	35 countries	KSS, Sollis *et al.*, STAR	Real black market with dollar	CPI	Monthly: 1973–1998	Converges to PPP via a STAR process
Chang *et al.* (2006)	22 African	Logistic unit root; also linear: KPSS, PP	Real with dollar	CPI	Monthly: 1980–2003	Rejects unit root for 6/22: PPP holds
Chortareas and Kapetanios (2004)	35 LDCs and emerging market economies	STAR and KSS	Black market; dollar based	CPI	Monthly: 1973–1998	Nonlinear method rejects stationarity for 19/35; ADF rejects 30/35
Chowdhury (2007)	Bangladesh	STAR	Real bilateral with USA, India, Euro, yen	CPI	Monthly: 1994–2002	Symmetric nonlinear adjustment towards PPP
Enders and Chumrusphonlert (2004)	Pacific nations	Threshold cointegration	Real bilateral with Japan, USA	CPI	Monthly: 1973–2000/2001	Holds with threshold, especially with USA
Holmes (2002)	13 Latin American	STAR	Real, bilateral with US dollar	CPI	Quarterly: 1973–2001	7 have nonlinear adjustment

Journal of Economic Surveys (2009) Vol. 23, No. 4, pp. 617–658

Table 4. *Continued.*

Author (year)	Countries	Methodology	Exchange rate	Variables	Time period	Key results
Leon and Najarian (2005)	26 countries; 13 LDCs	TVTAR, BSTR, Markov switching	Real effective	CPI		Unit root not robust
Li (2007)	3 high-volatility LDCs	Markov switching	Bilateral with US dollar		Monthly: Varies – 2004	Focuses on variance – high-volatility LDCs show more evidence of Markov-switching behaviour
Liew *et al.* (2004)	11 Asian countries	KSS	Real, dollar and yen based	CPI	Quarterly: 1968–2001	KSS rejects unit root in 8 of 11; ADF does not reject null
Liew *et al.* (2005)	Malaysia	Luukkonen and KSS	Real bilateral with US dollar	CPI and WPI	Quarterly: 1973–1997	Nonlinear, stationary, but inconclusive
Paya and Peel (2005)	4 high-inflation countries: Brazil, Colombia, Israel, Zaire	ESTAR	Real bilateral with US dollar	WPI	Monthly: 1972–1993	Nonlinear – supports ESTAR
Sarno (2000)	11 Middle Eastern	ESTAR	Real bilateral with US dollar	CPI	Quarterly: 1971–1994	Mean reversion
Smallwood (2005)	20 countries; includes LDCs	STAR	Real bilateral with US dollar	CPI for most	Monthly: 1973–2002	Evidence for nonlinearity

TVTAR, time-varying threshold autoregression; BSTR, bi-parameter smooth transition regression.

Journal of Economic Surveys (2009) Vol. 23, No. 4, pp. 617–658

and Nasir, 2002), smuggling (Bahmani-Oskooee and Goswami, 2003) and military spending (Bahmani-Oskooee and Goswami, 2005a). Other explanations have been proposed as well.

4. Conclusion

Many less-developed and transition economies suffer from lower productivity, higher inflation and tighter capital controls than the developed world. As a result, PPP might behave differently in these countries. Yet a relatively small proportion of the literature has concentrated specifically on LDCs. Keeping the challenges that LDCs face in mind, we have surveyed the literature to highlight the various empirical studies that have addressed PPP in LDCs and transition economies.

This survey shows that whereas linear unit-root tests have suffered from low power, thus tending to reject PPP, cointegration tests and panel studies have also produced mixed results. Models that incorporate structural breaks and other changes to the mean have improved their performance, however. Nonlinear techniques have performed somewhat better, but still have not conclusively 'proved' the PPP hypothesis in these countries. Although African countries most often show support for PPP, nations in Asia, Latin America and the former Eastern Bloc have done so less.

Many of the studies outlined here have operated under the implicit assumption that a true PPP relationship exists, only requiring an effective test to be found. One area where the literature is relatively lacking is in determining and isolating the causes of the failure of PPP. Certain studies, especially panel approaches, have been informative in this regard. Although such well-known factors as the Balassa–Samuelson productivity bias hypothesis and the effects of economic openness have been explored, studies that highlight such variables as government spending represent a new direction in this literature. These issues are especially relevant to transition economies as they grapple with such issues as price liberalization, exchange-rate policy and integration with the Euro, productivity adjustment and international competitiveness – all of which will be affected if PPP does not hold. Thus, researchers concerned with transition economies, as well as LDCs, are encouraged to apply these new advances in econometrics to validate PPP, or to discover the reasons why the relationship does not behave as expected.

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Note

1. 'Fractional integration', which is mentioned in this paper, is where a variable is neither I(1) nor I(0), but rather integrated of a fraction – where d for an I(d) variable is not an integer.

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