THE EXPLOSION OF PURCHASING POWER PARITY

by

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The theory of purchasing power parity (PPP) is one of the fundamental principles in international finance. It states that prices across countries should be equal when converted to a common currency (absolute PPP), or less strictly, the change in the exchange rate should be equal to the difference between the changes in the domestic and foreign price indexes (relative PPP). It is widely agreed that Gustav Cassel (20 October 1866 - 15 January 1945) is the father of the PPP doctrine, although this line of intellectual thought actually originated with Spanish scholars in the 16th century. Rigorous empirical examination of the theory did not appear until the 1960s, when evidence was found supporting PPP over long periods of time (see, for example, Friedman and Schwartz, 1963 and Gaillot 1970). The productivity bias hypothesis proposed by Balassa (1964) and Samuelson (1964) obtained considerable empirical support, and continues to be highly influential. During the past three decades, there have been heated debates about the validity of PPP and professional confidence in the theory has experienced considerable ups and downs.

With the move to flexible exchange rates in the early 1970s, it was generally assumed that the exchange rate would quickly adjust to changes in relative price levels. However, the high volatility of the exchange rates, in both nominal and real terms, rendered PPP theory almost untenable. Dornbusch (1976) proposed an overshooting model, temporarily mitigating some unease in the literature. He argued that the stickiness of goods prices, together with continuously clearing asset markets, are the main reasons for deviations from PPP. Before the mid-1980s empirical tests were concerned with simple specifications of PPP which centred on coefficient restrictions, using the methods of ordinary and generalised least squares, which tended to strongly reject PPP except for

*This paper is based on my PhD thesis at The University of Western Australia. I would like to thank Ken Clements for his excellent supervision and constant encouragement. The help from Meher Manzur and useful comments from Paula Madson are also gratefully acknowledged. All errors are my own.
hyperinflation countries. This line of research reached its high-water mark in the early 1980s with a paper published by Frenkel (1981) entitled "The Collapse of Purchasing Power Parities during the 1970s". It is now widely agreed that such straightforward tests for PPP, which Froot and Rogoff (1995) term the "Stage-One tests", took no account of the possible non-stationarity in relative prices and exchange rates, and thus possibly produced spurious results.

In the second half of the 1980s, with the advancement of time-series techniques, many PPP studies concentrated on testing the efficient-markets version of PPP (that is, the hypothesis of random walk behaviour in real exchange rates), but could not reject the null of a random walk (see, e.g., Adler and Lehmann, 1983, Meese and Rogoff, 1988, Mark, 1990). There was also a sizeable amount of work which failed to find cointegration between nominal exchange rates and relative prices (see, e.g., Corbae and Ouliaris, 1988, Enders 1988, and Patel 1990). The failure of PPP to pass empirical scrutiny further sapped confidence in its practical usefulness.

The late-1980s saw a rebirth of interest in PPP, mainly due to the advent of unit-root econometrics. As conventional unit root tests have low power, researchers have circumvented the problem by using (i) longer periods of data; and (ii) cross-country-time-series analysis, known as 'panel data' techniques. Research from long-horizon data generally finds increasing evidence of convergence to PPP. Well-known examples of long-horizon studies include Frankel (1986), Edison (1987), Diebold et al. (1991) and Lothian and Taylor (1996). However, there still remains scepticism about inferences of real exchange rate behaviour based on data across exchange rate regimes (Frankel and Rose, 1996, Lothian, 1998), or over long historical periods of peace and war (Johnson, 1993, Grilli and Kaminsky, 1991). As data are only available over long time spans for industrial countries, the favourable results may be exaggerated by the survivorship bias problem raised by Froot and Rogoff (1995). The large size bias of tests for PPP based on long-horizon data has been confirmed in several studies (see, for example, Engel and Kim 1999, Engel 2000). By the late-1990s, there has been only a few additional investigations of PPP using long time-series data (for example, Guimarães-Filho, 1999, Kuo and Mikkola, 1999, Parkes and Savvides, 1999). It seems that this remedy for the problem of low test power has now lost favour.
The use of panel data has become increasingly popular among researchers to examine the behaviour of real exchange rates over relatively short time periods, such as during the post-Bretton Woods era. Hakkio (1984) and Abuaf and Jorion (1990) were early papers that applied panel data methods to PPP tests. Evidence in favour of long-run PPP using cross-sectional datasets from industrial countries is reported in Wei and Parsley (1995), Frankel and Rose (1996), Oh (1996), Wu (1996), Papell (1997), Papell and Theodoridis (1998), and Higgins and Zakrajšek (1999). On the other hand, mixed results have been found for parity reversion for a limited number of panel analyses from developing countries. Phylaktis and Kassimatis (1994) support the validity of long-run PPP for eight Pacific Basin countries over the period 1974 to 1987, while Wu and Chen (1999) find no evidence of PPP using the data from the same eight countries for the period of 1980 to 1996. Through unit root tests from heterogeneous panels and variance ratio tests, Luintel (2000) finds support for PPP using data for eight Asian developing countries. A number of other methodologies have been used to test for PPP during the last decade, including the still-popular cointegration techniques, variance ratio tests, structural-break tests, non-linear approaches to mean reversion and so on.

The revival of interest in PPP has been documented in a number of comprehensive and influential surveys -- see Breuer (1994), Froot and Rogoff (1995), MacDonald (1995) and Rogoff (1996). This paper aims to provide an up-to-date survey of the contemporary literature on PPP. It covers the literature that has appeared up until July 2000, with the major focus on the research from the last decade. The next section examine the research into and interests in PPP, while Section 2 gives a geometric analysis of PPP theory. Section 3 is devoted to issues related to deviations from parity, including two measures of the PPP deviations. In Section 4 we summarise recent empirical evidence on PPP and the last section offers some concluding remarks.

1. HOW MUCH IS BEING WRITTEN ON PPP?

The amount of research into PPP has exploded during the past three decades. The Big Mac Index (BMI), invented by The Economist magazine in 1986, has played a major role in popularising PPP and bringing its practical implications to the attention of financial
markets. As a way of measuring the extent of professional interest in PPP, this section reports results of searching for (i) PPP in Econlit, a widely-used economic indexing database produced by the American Economic Association;\textsuperscript{1} and (ii) the Big Mac Index in Google, a popular search engine on the world wide web.

To quantify the growth in the literature on PPP, we conducted a keyword search for the term "purchasing power parity" or "PPP" in EconLit. As we need to compare the amount published on PPP with something, we also searched for four broad additional economic terms -- inflation, unemployment, interest rate and exchange rate -- and another relatively narrow term, foreign direct investment (FDI).\textsuperscript{2} We recorded the number of research articles on each topic in the 1970s, 1980s, 1990s and from January to July 2000. Figure 1 plots, on the left-hand axis, the number of articles in each decade for the six topics. As the vertical axis uses a logarithmic scale, the change in the height of the bars from one decade to the next indicates the exponential rate of growth for each topic. The right-hand vertical axis gives the average growth rate, on an annual basis, for each topic. It can be seen that PPP has grown at an average annual rate of 18 percent p.a., second only to FDI. This growth rate clearly reflects that the research interest in PPP has been expanded very substantially over the last thirty years. Thus, rather than "collapsing", PPP research can be described as "exploding".

Since the introduction of the Big Mac Index (BMI) by The Economist in 1986, financial markets have become interested in PPP as a practical approach to valuing currencies and in making international price comparisons. Economic research on this index has evolved into an important strand of literature called "Burgernomics".\textsuperscript{3} As a way to measure the extent of such interest, we searched for the exact phrase "Big Mac

\textsuperscript{1} The source material of Econlit includes international economic journals, essays, research papers, books, dissertations, book reviews, and working papers. Years of coverage are from 1969 to the present with approximately 26,000 records added annually. Our search is done through the licensed Econlit website at The University of Western Australia: http://ovid.library.uwa.edu.au/ovidweb/ovidweb.cgi.

\textsuperscript{2} Foreign direct investment is chosen as a keyword due to its extraordinary growth over the past few decades.

\textsuperscript{3} In the Burgernomics literature, Cumby (1996) is the first paper which uses the BMI to tests for PPP. Pakko and Pollard (1996) and Click (1996) examine the nature of deviations from PPP, while Annaert and Ceuster investigate the value of BMI from an investment perspective. Ong (1997) improves upon BMI and proposes the "No-Frills Index" to value currencies. Applications of Burgernomics include Ong (1998a) who analyses the Asian currency crisis, Ong (1998b) and Ong and Mitchell (2000) which examine the purchasing power of earnings around the world and real academic salaries.
Index” in a web search engine -- Google. This resulted in 697 entries. We categorised these BMI web sites according to the language they use and their institutional domains and the search results are written in the 17 frequently-used languages and the remaining 30 percent are in the language not specifically identified by Google. English web sites are the most frequent, followed by European languages. Developing countries are also aware of this widely-quoted invention from The Economist. From the right panel of Table 1, it can be seen that BMI is used in all sectors. About 40 percent of the BMI web pages are created by commercial institutions, suggesting the widespread practical usefulness of the BMI. Another 20 percent of the BMI pages are related to educational activities. Even serious international organisations (which have the domain .org) use this metric of relative currency values -- presumably because it is simple, timely, and, most importantly, accurate for policy-makings.

4 The address of the Google search engine is http://www.google.com.
5 Note that (1) to narrow down the search, we use an additional constraint “not computer”; (2) all the search results in Google refer to the returned entries excluding pages similar to those displayed; and (3) another 18 entries from Google contain only the word “Burgernomics”, but not the phrase “Big Mac Index”.
TABLE 1
BIG MAC INDEX SEARCH RESULTS

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2. THE GEOMETRY OF PPP

This section presents a geometric analysis of PPP theory by examining the two perspectives on traditional PPP: (1) The exchange rate-relative price relationship; and (2) the relationship among exchange rates, money and prices.

A natural starting point of the traditional view of PPP is its central building block -- the law of one price, which states that the price of an identical good in two countries should be equal when converted to a common currency. The basic mechanism is arbitrage -- buying in those countries where the price is low and selling where high -- will eliminate the differentials, at least over the medium term. Applying this idea to the price of a market basket, we have \( P_t = S_t P_t^* \), where \( P \) is the domestic price level, \( P^* \) the foreign price level, and \( S \) the exchange rate. This implies the absolute version of PPP, i.e., \( S_t = P_t / P_t^* \), whereby the absolute PPP of a currency is determined by the ratio of the domestic price level to the foreign price level. In terms of natural logarithms, we have

\[
(1) \quad s_t = \ln P_t - \ln P_t^*.
\]
Given the difficulties with the construction of an appropriate common basket of goods for implementing absolute PPP, a weaker version of PPP is often considered. This relative version of PPP is based on price movements, which are measured by changes in price indexes relative to a base period. Relative PPP allows for a constant gap in absolute PPP described in equation (1),

\[ s_t = p_t - p_t^* - k. \]

Let expression (2) hold for the base period, 0, so that \( s_0 = p_0 - p_0^* - k \). We can then subtract this equation from (2) to yield

\[ s_t - s_0 = \tilde{p}_t - \tilde{p}_t^*, \]

where \( \tilde{p} = p_t - p_0 \) and \( \tilde{p}^* = p_t^* - p_0^* \) are changes in price levels of the domestic and foreign country respectively, with the same base starting-point, i.e., inflation at home and abroad. Expression (3) is the usual presentation of relative PPP in textbooks. It states that the change in the exchange rate should offset the inflation differential.\(^6\) To allow for stochastic deviations from relative PPP, we add a stationary error term to equation (2),

\[ s_t = p_t - p_t^* - k + e_t. \]

We draw on the conceptual framework of MacDonald and Stein (1999) to illustrate the above three versions of traditional view of PPP. Figure 2 plots the nominal exchange rate \( s \) against relative prices, \( r = p - p^* \). Panel A case presents the case when \( k = e = 0 \), so that the 45° line passing through the origin corresponds to absolute PPP. Any combination of \( s \) and \( r \) that lies above the line implies an undervaluation of the home country currency, while points below represent overvaluation. Panel B allows \( k \neq 0 \) and \( e = 0 \), which is relative PPP. Here the 45° line does not pass through the origin, but still an increase in the relative price leads to an equi-proportional depreciation of the currency, as is illustrated by the movement from the point A to B, whereby \( s_2 - s_1 = r_2 - r_1 \).

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\(^6\) Equations (2) and (3) are two presentations of relative PPP. Note that relative PPP expressed in (2) includes absolute PPP as a special case with \( k = 0 \). It can only be tested with price levels, whereas (3) can be tested directly with price indexes, or price indexes computed from price levels.

\(^7\) Maeso-Fernández (1998) points out a frequent mistake that most researchers make when formulating stochastic deviations from relative PPP — adding the stationary error term to (3). In such a case, the real exchange rate follows a random walk and relative PPP does not hold.
FIGURE 2
EXCHANGE RATES AND RELATIVE PRICES

A. Absolute PPP

B. Relative PPP

C. Stochastic Deviations from Relative PPP
The central line in Panel C corresponds to relative PPP and is the centre-of-gravity relationship when there are stochastic shocks in the short run. Suppose for simplicity that $e$ is a discrete random variable and that $e_1 < 0$ and $e_2 > 0$ are its only possible values. When the shock is $e_1 < 0$, we obtain a new lower, 45-degree line, which has an intercept of $-k + e_1$; similarly, $e_2 > 0$ results in the upper line in Panel C. Consider the situation in which the exchange rate is $s$ and relative prices $r_1$, so we are located at the point $W$ in Panel C. If there is now the same increase in relative prices as before, so that $r$ rises from $r_1$ to $r_2$, then, in the presence of the shock $e_1$, we move to the point $X$ with the rate depreciating to $s_0$. With the shock $e_2$, the same relative price $r_2$ leads to an exchange rate of $\tilde{s}$, as indicated by point $Y$. More generally, if relative prices change within the range $[r_1, r_2]$ and if the shocks can now vary continuously within the range $[e_1, e_2]$, then the exchange rate/relative price point lies somewhere in the shaded parallelogram $WXYZ$. It is to be noted that as the height of this parallelogram exceeds its base, the possible range of the exchange rate, $\tilde{s} - s$, exceeds that of prices, $r_2 - r_1$. This "overshooting" accords with the idea that in the short run exchange rates are considerably more variable than relative prices. This contrasts with the situation in Panels A and B whereby the exchange rate is proportional to prices and illustrates the importance of stochastic shocks to the PPP relationship.

Next, we examine the PPP theory from the perspective of the quantity theory of money and present a geometric analysis of the relationships among exchange rates, money and prices. The quantity theory of money (QTM) is built on the equation of exchange which shows the relationship between the money supply, velocity, prices and volume of transactions. The transactions version of QTM is $MV = PT$, where $M$ is the supply of money balances, $V$ is the velocity or rate of circulation of these money balances, $P$ is the general level of prices of all transactions, and $T$ is the number of transactions. As $V$ and $T$ are fixed, an increase in the supply of money will lead to a proportionate increase in the price level, i.e., $\hat{P} = \hat{M}$, where a circumflex ("^\wedge") denotes percentage change. Figure 3 shows this relationship.

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8 This material mainly draws on the lecture notes of International Finance 415 by Ken Clements at The University of Western Australia. See also Clements (1981).
To relate QTM to PPP, we decompose the goods which make up the general price level $P$ into traded and non-traded goods. Then we have the price level function $P = P(T, N)$ which is homogeneous of degree one. This function is plotted as the downward sloping convex curve $AA$ in Figure 4 and is called the "absolute price schedule" along which the price level is a constant. The distance of the absolute price schedule from the origin measures the price level. Suppose that the relative price $r = P_T / P_N$ is constant, so that the two prices must lie somewhere along the ray OP. For the economy to simultaneously satisfy monetary equilibrium and for the relative price to be $r$, overall equilibrium must be located at the point $E$ where the two curves intersect. A doubling of the money supply moves the absolute price schedule from $AA$ to $A'A'$, the price level doubles and with the relative price unchanged, the new equilibrium is at the point $E'$. The homogeneity of the price level function $P = P(T, N)$ means that the effect of the doubling the quantity of money is to double both sectoral prices $P_T$ and $P_N$. 
Figure 5 combines the above two figures with the money stock added to the lower quadrant of Figure 4. PPP theory comes into play with the additional assumption that it holds for traded goods, i.e., $P_T = S P^*_T$, where $P^*_T$ is the foreign price level of traded goods. The left quadrant of Figure 5 shows this relationship. As before, a doubling of the money stock doubles the general price level and the domestic price of traded goods also doubles. With the foreign traded goods price unchanged at $P^*_T$, the exchange rate depreciates by 100 percent, i.e., $S_1 = 2S_0$, as can be seen from the left-hand panel of Figure 5.

An important case of an interaction between real and monetary phenomena in this area is the "productivity bias" hypothesis of Balassa (1964) and Samuelson (1964). The above framework can be used to illustrate the key idea. Suppose there are two countries, one rich and one poor. The productivity bias hypothesis states that the rich country has higher productivities in producing both traded and non-traded goods, but is proportionately more productive in traded goods, relative to the poor country. This could be because nontraded goods tend to be services, which are labour intensive, and are not so amenable to productivity improvement. The higher productivity of the traded goods sector in both countries raises wages not only in its own sector, but also economy-wide.
wages. As non-traded goods are usually labour intensive, this has the effect of making the relative price of these goods higher in the rich country, where wages are higher. In other words, traded goods (in terms of nontraded goods) are cheaper in the rich country as compared to the poor country, so that \( r^R < r^P \). To isolate the impact of the differing structure of relative prices, let the two countries share the same absolute price schedule, so that the overall price level is the same in the two countries. Application of PPP to these price levels would then imply that the cost of unit of foreign exchange would be identical in the two countries, \( S^R = S^P \). But, the situation is different if we apply PPP to the traded goods only. As Figure 6 shows, \( r^R < r^P \) implies that \( S^R < S^P \), so that the rich country's currency is now more highly valued than that of the poor country.
FIGURE 6
PRODUCTIVITY AND EXCHANGE RATES

The rich country

The poor country
The implications of the above analysis are as follows:

(i) Application of PPP to price levels indicates that the currencies of the two counties should have the same value.

(ii) PPP for traded goods only indicates that the currency of the rich country is worth more.

(iii) If currencies are in fact priced according to traded goods PPP, whereas one values them according to price-level PPP, (i) and (ii) above jointly imply that the currency of the rich (poor) country is over (under) valued. This is the productivity hypothesis.

3. DEVIATIONS FROM PARITY AND THE SPEED OF ADJUSTMENT

As Rogoff (1996) points out, every reasonable theoretical model suggests that there should be at least some temporary component to PPP deviations. This section first explores the notion of deviations from PPP from both the traditional and efficient-markets perspectives of PPP. Then we discuss the concept of the half-life as a measure of the speed of convergence to long-run PPP. Finally, a summary of estimates of the half-life of PPP deviations from a variety of studies is presented.

Recall from Section 2 that stochastic deviations from traditional PPP are described in equation (4) as \( s_t = p_t - p_t^* - k + e_t \), whereby the real exchange rate is \( -k + e_t \). The nature of the error term \( e_t \) determines the validity of PPP. Following Maeso-Fernández (1998), we write \( e_t \) as a moving average of a white-noise process, \( \{ e_t \} : e_t = a(L)e_t \), where \( a(L) \) is a polynomial in the lag operator \( L \) and \( a(L) = \sum_{i=0}^{N} a_i L^i \). There are three possibilities for the PPP deviations \( e_t \):

(i) If the polynomial \( a(L) \) is of zero degree (i.e., \( N = 0 \), so that \( a(L) = a_0 \)), PPP deviations \( e_t \) are serially-uncorrelated white noise. In such a case, the shocks to PPP only have a transitory effect.

(ii) If \( a(L) \) is of greater-than-zero degree (\( N > 0 \)) and its roots are outside the unit circle, a real shock has permanent effects on the current level of the real exchange rate, but the effects gradually die out. In this case, PPP deviations are persistent, but relative PPP holds in the long run. The real exchange rate thus displays mean reversion.
If \( a(L) \) has greater-than-zero degree and its roots are inside the unit circle, all previous real shocks have permanent effects on the current exchange rate level. In this case, \( e_t \) is a non-stationary process, implying that the relative PPP does not hold in the long-run.

The above analysis examines the traditional view of PPP, i.e., PPP as a relationship between the exchange rate and relative prices. Next, we examine deviations from PPP from the perspective of the efficient-markets view of PPP and review two alternative measures of the speed of convergence. The traditional and efficient-markets views are closely related to each other and test for PPP from different angles, although they seem to be contradictory with opposite economic implications.\(^9\)

The efficient-markets view, initiated by Magee (1978), Roll (1979) and Darby (1980), examines the stochastic behaviour of real exchange rates. It states that if expectations are rational, changes in the real exchange rates should be serially uncorrelated. Thus the real exchange rate should follow a random walk process. One of the implications of this random walk hypothesis is that changes in the real exchange rate cannot be predicted using past information. The base-line test for the efficient-markets view of PPP is equivalent to testing for a unit root in the real exchange rate against the stationarity alternative. Consider the following simple data-generating process:

\[
H_0 : q_t = \alpha + \beta q_{t-1} + u_t, \quad \beta = 1,
\]

\[
H_1 : q_t = \alpha + \beta q_{t-1} + u_t, \quad 0 < \beta < 1,
\]

where \( q_t \) is the real exchange rate defined as \( q_t = p_t - s_t - p_t^* \); \( \alpha \) and \( \beta \) are the intercept and the speed-of-adjustment parameters and \( u_t \) is a disturbance term.\(^10\) From equation (4), we can see that \( q_t = k - e_t \), so that the real exchange rate represents the deviation from PPP. Stationarity of the real exchange rate implies that deviations from PPP are transitory and eventually die out.

\(^9\) See, e.g., MacDonald and Marsh (1999) and Masseo-Fernández (1998), for discussions of the two views of PPP.

\(^10\) In testing for the efficient-markets view of PPP, in practice a more extended time-series model is typically used. The most common data-generating process used is the augmented Dickey-Fuller framework: \( \Delta q_t = \alpha + \rho q_{t-1} + \sum_{i=1}^{\infty} \lambda_i \Delta q_{t-i} + \eta_t \), where the lagged real exchange rate changes are added to control for serial correlation. Under the null, \( \alpha = \rho = 0 \). Under the alternative, \( \rho < 0 \).
Consider again the above data-generating process,

\[ q_t = \alpha + \beta q_{t-1} + u_t, \]  

averaging over \( t = 2, \ldots, T \), we have

\[ \bar{q}_t = \alpha + \beta \bar{q}_{t-1} + \bar{u}_t, \]

where the bars denote means. For a process with sufficiently long time intervals, \( \bar{q}_t = \bar{q}_{t-1} = \bar{q} \). Subtracting equation (6) from equation (5) and ignoring the disturbance terms (which represent the deviations from the deterministic relationship), we obtain through successive substitution

\[ d_t = d_0 \beta^t, \]

where \( d_t = q_t - \bar{q} \) is the value of the current deviation and \( d_0 \) is the value of the initial deviation. Under stationarity, the speed-of-adjustment parameter \( \beta \) in equation (5) is less than one, thus \( \beta^t \to 0 \) and the deviation \( d_t \to 0 \) when \( t \to \infty \). A value of \( \beta \) of .97, for example, means that 3 percent of the PPP deviation vanishes per period.

More generally, let the real exchange rate be generated by a more complex process:

\[ q_t = \alpha + \sum_{j=1}^{m} \beta_j q_{t-j} + u_t. \]

As in equilibrium \( E(q_t) = E(q_{t-j}) \) for \( j = 1, \ldots, m \), the speed of convergence is the sum of the coefficients of all the lags, i.e., \( \sum_{j=1}^{m} \beta_j \). Accordingly, stationarity of \( \{q_t\} \) requires \( 0 < \sum_{j=1}^{m} \beta_j < 1 \).

An alternative measure of the speed of adjustment is the “half-life” of a process, a concept originally from physics. It measures the decay of a substance comprising of a large number of identical particles. The half-life is the time taken by a given amount of substance to decay to half its mass. Figure 7 shows the remaining amount of particles as a function of time. Here, \( H \) is the half-life of the process. After a second half-life, one half of the remaining particles will have decayed, leaving 1/4 of the original amount. After three half-life intervals, 1/8 of the original amount remains and so on. Thus the decay process can be expressed as:

\[ d_t = d_0 e^{-\frac{t}{H}}, \]
FIGURE 7

THE TIME PATH OF A MEAN REVERSION PROCESS

where $T$ is the time required for the total amount to decay, usually called the "life-time". According to the definition of the half life, $e^{-H/T} = d_0 / d_t = 1/2$, so that

(10) \[ H = T \ln 2. \]

This relationship shows that the half-life is an alternative measure of the total time required for mean reversion, $T$. It indicates how long it takes for the impact of a unit shock to dissipate by half. Comparing expressions (7) and (9), we obtain the relationship between the life-time $T$ and the mean-reversion speed $\beta$: $T = -1 / (\ln \beta)$. Substituting this into (10), we obtain

(11) \[ H = - \ln 2 / (\ln \beta). \]

If the data-generating process is in the form of equation (8), expression (11) then becomes $H = - \ln 2 / [\ln (\sum_{i=1}^{n} \beta_i)]$.

Empirically, the half-life of PPP can be estimated not only from an autoregressive data generating process of the real exchange rate, but also from variance ratios. The simplest variance ratio for a time series $\{ y_t \}$, proposed by Cochrane (1988), is $R(k) = \text{var}(y_{t+k} - y_t) / \text{var}(y_{t+1} - y_t)$, where $k = 2, \cdots$. This expression is the variance of the $k^{th}$ difference divided by that of the first difference. When the value of $k$ is sufficiently large, it can be shown that $R(k)$ is approximately the variance of the unit-root component of the real exchange rate. Thus the time required for $R(k)$ to diminish to half of its size is an alternative estimator of the half-life of real exchange rate innovations.
Table 2 summarises estimates of half-lives from various studies in the PPP literature; these estimates are presented in descending order in Figure 8. It can be seen that most of the estimates lie between 3 and 5 years. The median and mean of half-lives are 4 and 4.1 years, respectively. These figures are in broad agreement with the length of

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<td>Fung and Lo (1992)</td>
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<td>Six industrial countries</td>
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<td>Wei and Parsley (1995)</td>
<td>a 4.25</td>
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<td>b 4.75</td>
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<td>Frankel and Rose (1996)</td>
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<td>Cumby (1996)</td>
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<td></td>
<td>b 5.9</td>
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<td>Papell (1997)</td>
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<td>b 2.8</td>
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<td>Higgins and Zakrajšek (1999)</td>
<td>a 5</td>
<td>Europe, CPI</td>
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<td></td>
<td>b 3</td>
<td>Europe, WPI</td>
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<td></td>
<td>c 2.5</td>
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<td>d 11.5</td>
<td>Open economies, CPI</td>
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<td>Cheung and Lai (2000)</td>
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<td>Standard error of mean</td>
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Notes: 1. Where a study contains more than one estimate of half-life, we use a, b, c, etc. to distinguish different estimates, with additional information provided in the final column of the corresponding row.
2. Where a study does not report the half-life directly, we compute it from the speed-of-adjustment estimate (on an annual basis) using $H = -\ln 2 / (\ln \beta)$ or $H = -\ln 2 / (\ln (\sum_{j=1}^{k} \beta_j))$.
3. In those cases where the underlying data are not annual and the parameter estimated is $\beta$, we compute the speed of adjustment per annum as $\beta^n$, where $n$ is the number of periods per year.
4. Cheung and Lai (2000) report the range of half-life estimates for two groups of countries. To compute the mean and its standard error in the last two rows of this table, we use 3.5 and 2 years as the respective point estimates.
the long run insofar as PPP is concerned reported in the survey paper of Froot and Rogoff (1995) of four to five years. This increasing consensus boosts professional confidence in long-run PPP despite the fact that PPP deviations are quite persistent.

4. RECENT EMPIRICAL FINDINGS

This section gives an overview of the most recent empirical evidence regarding PPP which has emerged during the course of the theory's resurrection over the 1990s. Table 3 gives a list of the most recent work on PPP.\[11\]

\[11\] Note that this review of the recent empirical evidence was completed in July 2000.
To review the empirical evidence using a variety of techniques, we classify these papers into three kinds of samples: (1) Industrial countries; (2) mixed samples of both developed and developing countries; and (3) purely developing countries.

Panel A of Table 3 shows that recent evidence from industrial countries is generally supportive of long-run PPP, and interestingly, such favourable results are obtained through a diverse variety of econometric techniques. Bayoumi and MacDonald (1999), Flöres et al. (1999), Koedijk et al. (1998), Papell (1997), and Papell and Theodoridis (1998) are some examples in favour of PPP using panel frameworks. Maeso-Fernández (1998) find evidence of mean reversion of real exchange rates using variance ratio tests. Edison et al. (1997) employ cointegration techniques. Michael et al. (1997) apply a non-linear approach to mean reversion. Parkes and Savvides (1999) use a sequential model to search for endogenous breaks and find that the real sterling rate reverts to a shifting mean. Sjaastad (1998) uses a commodity currency approach to model the exchange rates and commodity prices.

Negative results for PPP from industrial countries are reported in Baum et al. (1999), Engel (2000), Li (1999) and O'Connell (1998). It is to be noted that most studies examine real exchange rates against the US dollar, and there are only a limited number of studies using the German mark as the base currency (e.g., Anker, 1999, Engel et al. 1997, Flöres et al., 1999, Koedijk et al., 1998, and Papell, 1997). The common finding is that PPP holds more strongly for the German mark than the US dollar exchange rates. Lothian (1998) argues that this is caused by the large depreciation of the dollar during the early and mid-1980s and the strong appreciation afterwards.

Mixed evidence is found in studies whose samples include both industrial and developing countries; see Panel B of Table 3. Wu and Chen (1999) fail to find evidence for PPP using two panel unit root tests. Lee (1999) tests PPP for 13 Asia Pacific countries using a generalised error correction model and finds support for PPP for countries. Favourable empirical results from mixed-samples are reported in Higgins and Zakrajšek (1999) who include eight developing countries in their open-economy panel.

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12 Some earlier examples using the German mark as the base currency are Mark (1990), Edison and Fisher (1991) and Fisher and Park (1991).
### TABLE 3
RECENT EMPIRICAL EVIDENCE ON PPP

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<tr>
<td>Anker (1999)</td>
<td>Panel</td>
<td>18 (14) industrial countries</td>
<td>1974-1997 (Q)</td>
<td>CPI (WPI)</td>
<td>Panel unit root test (GLS)</td>
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<td>Baum et al. (1999)</td>
<td>Time-series</td>
<td>17 countries, 12 countries</td>
<td>1973-95 (M)</td>
<td>CPI and WPI</td>
<td>Fractional co-integration and structural break tests</td>
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<td>Time-series</td>
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<td>1974-92 (Q)</td>
<td>CPI</td>
<td>Cointegration</td>
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<td>Engel (2000)</td>
<td>Time-series</td>
<td>US/UK</td>
<td>1970-95 (Q)</td>
<td>GDP deflator</td>
<td>Unit root and cointegration tests</td>
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<td>Engel et al. (1997)</td>
<td>Panel</td>
<td>4 pairs of cities in the US and Europe</td>
<td>1978-94 (M)</td>
<td>CPI</td>
<td>GLS applied to a system of error-correction models</td>
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<td>Flores et al. (1999)</td>
<td>Panel</td>
<td>10 industrial countries</td>
<td>1973-94 (M)</td>
<td>CPI</td>
<td>Panel unit root test (SUR-GLS)</td>
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<td>Koedijk et al. (1998)</td>
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<td>17 industrial countries</td>
<td>1972-96 (Q)</td>
<td>CPI</td>
<td>A numeraire-invariant panel methodology</td>
<td>Yes</td>
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<td>Li (1999)</td>
<td>Time-series</td>
<td>29, 26 and 25 OECD countries</td>
<td>1974-96 (A)</td>
<td>CPI</td>
<td>Hierarchical model</td>
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<td>O'Connell (1998)</td>
<td>Panel</td>
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<td>1973-95 (Q)</td>
<td>CPI</td>
<td>Panel unit root test (GLS)</td>
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<td>Michael et al. (1997)</td>
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<td>Nonlinear adjustment (STAR model)</td>
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<td>Parkes and Savvides (1999)</td>
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<td>SUR and sequential test for structural breaks</td>
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<td>Sjaastad (1998)</td>
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<td>Switzerland</td>
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<td>GDP deflator, CPI and PPI</td>
<td>Commodity currency</td>
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<td>Taylor and Sarno (1998)</td>
<td>Panel</td>
<td>US, UK, France, Germany, Japan</td>
<td>1973-96 (Q)</td>
<td>CPI and GDP deflator</td>
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<tr>
<td>Higgins and Zakrajšek (1999)</td>
<td>Panel</td>
<td>11 European countries, 12 OECD countries and 17 open economies</td>
<td>1973 (or 76 or 79)-97 (Q)</td>
<td>CPI and WPI</td>
<td>Four panel unit root tests</td>
<td>Yes</td>
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<tr>
<td>Lee (1999)</td>
<td>Time-series</td>
<td>13 Asia Pacific countries</td>
<td>1957-94 (Q)</td>
<td>CPI and WPI</td>
<td>Generalised error correction</td>
<td>Yes</td>
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<tr>
<td>Wu and Chen (1999)</td>
<td>Panel</td>
<td>9 Pacific Basin countries</td>
<td>1980-96 (M)</td>
<td>CPI and WPI</td>
<td>Two panel unit root tests</td>
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<td><strong>C. Developing countries</strong></td>
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<td>Bahmani-Oskooee (1998)</td>
<td>Time-series</td>
<td>11 Middle Eastern countries</td>
<td>1971-94 (Q)</td>
<td>CPI</td>
<td>Stationarity and ADF tests</td>
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<td>Boyd and Smith (1999)</td>
<td>Panel</td>
<td>31 developing countries</td>
<td>1966-90 (Q)</td>
<td>CPI</td>
<td>Panel unit root and cointegration tests</td>
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<td>Doğanlar (1999)</td>
<td>Time-series</td>
<td>India, Indonesia, Pakistan, Turkey and Philippines</td>
<td>1980-95 (Q)</td>
<td>CPI</td>
<td>Cointegration</td>
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<tr>
<td>Guimarães-Filho (1999)</td>
<td>Time-series</td>
<td>Brazil</td>
<td>1855-1990 (Q)</td>
<td>Unknown</td>
<td>Robust rank test</td>
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<td>Luintel (2000)</td>
<td>Panel</td>
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<td>1958-89 (M)</td>
<td>CPI</td>
<td>Panel unit root and variance ratio tests</td>
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<td>Sarno (2000)</td>
<td>Time-series</td>
<td>11 Middle Eastern countries</td>
<td>1973-94 (Q)</td>
<td>CPI</td>
<td>Multivariate nonlinear models</td>
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Note: In the column headed “Sample period”, M denotes monthly data, Q quarterly and A annual.
and Cheung and Lai (2000) who find evidence of PPP mean-reversion through a country-by-country unit-root testing approach.

Due to limited data availability and quality, there are only a handful of studies which examine the validity of long-run PPP for developing economies. Panel C of Table 3 lists such papers. Empirical results from the developing world are in disagreement. Using cointegration techniques, Doğanlar (1999) finds evidence in favour of PPP for only one among five Asian developing countries. Salehizadeh and Taylor (1999) examine 27 emerging economies in Europe, the Americas, Asia and Africa. Their results obtained from cointegration support PPP for more than half of the countries and strongly reject the symmetry and proportionality conditions. In Boyd and Smith (1999), who focus on 31 developing countries, PPP is strongly supported using panel unit root tests, but only weakly supported using cointegration tests. The panel cointegration analysis of Nagayasu (1998) reveals that the behaviour of parallel market exchange rates of 16 African countries is consistent with long-run PPP.

There are a number of studies for developing countries using tests other than cointegration. Luintel (2000) confirms the stationarity of black-market real exchange rates for eight Asian developing countries using both panel unit root and variance ratio tests. Using the robust rank test, Guimarães-Filho (1999) cannot reject the existence of a unit root in Brazilian real exchange rates for more than a century. Evidence of PPP from Middle-Eastern countries are provided in Bahmani-Oskooee (1998) and Sarno (2000); the former uses conventional univariate tests and find mixed results, and the latter strongly supports PPP using multivariate nonlinear models.

5. CONCLUSION

In a nutshell, research on PPP has been exploding in the past three decades, especially during the last ten years. With the use of increasingly powerful test techniques, the conclusions concerning the validity of PPP are becoming more and more reliable.

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13 Recall from Section 2 that the absolute PPP is expressed in equation (1) as $s_t = p_t - p_t^*$. Expressing this in regression form, we have $s_t = \alpha_1 p_t - \alpha_2 p_t^* + u_t$. Symmetry requires that $\alpha_1 = \alpha_2$ and proportionality requires that $\alpha_1 = \alpha_2 = 1$. 

23
The increasing evidence favouring PPP has strengthened confidence in PPP. As Taylor and Sarno (1998) put it, “..... it seems that the profession’s confidence in long-run PPP, having been low for a number of years, may itself be mean reverting” (p. 308).

The implications of PPP holding in the long run are no less than profound. For example, PPP means that nominal devaluations are just inflationary in the long run and have no impact on the country’s competitiveness. A further implication of PPP holding in the long run is that it can be used as a convenient way to define equilibrium exchange rates. For example, Lan (2001) estimates the equilibrium rates for 16 countries using the Big Mac Index published by The Economist magazine. It is found that real exchange rates are stationary using this single-good index, and the estimated equilibrium exchange rates are quite similar to those derived from more complex methodologies. The attractions of this approach are its modest data requirement (Big Mac prices), the minimal economic structure on the problem and, above all, its simplicity.

Concerning the future direction of the research on PPP, there are at least two important issues to be resolved. First, the purchasing power parity puzzle summarised by Rogoff (1996): How can one reconcile the excessively high volatility of real exchange rates in the short-term with seemingly “long” half-life of deviations from PPP, i.e., four to five years? Second, the economic underpinnings of deviations from PPP, as pointed out by Higgins and Zakrajšek (1999): Economists should move beyond the purely statistical issue of whether the real exchange rate contains a unit root, to focus on the economic sources of deviations from PPP, which may comprise persistent and/or transitory components.
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