

# A Survey of Recent Empirical Tests of the Purchasing Power Parity Hypothesis \*

## Introduction

The Purchasing Power Parity (PPP) hypothesis postulates that the equilibrium exchange rate between any pair of currencies is equal to the ratio between domestic and foreign prices (absolute version) or that the equilibrium changes in exchange rates match inflation differentials (relative version). Many tests of these different versions of PPP have been reported in the literature, especially since the introduction of flexible exchange rates in 1973 and the renewal of interest in the validity of PPP.

The aim of this paper is to review the empirical literature on PPP in the period of floating exchange rates, 1973-1990,<sup>1</sup> with special attention to the studies addressing the issue of the long run validity of the hypothesis. The plan of the paper is as follows: Section 1 describes the different versions of PPP. Section 2 outlines several theoretical reasons put forward to explain (temporary and/or permanent) deviations from PPP. Section 3 analyses some empirical problems common to the different studies. Section 4 surveys the results of a number of recent empirical studies of PPP in terms of both methodology and most important findings. The emphasis of this section is on the econometric technique used by different authors, and this leads us to separate short run analyses from long run analyses (with some arbitrariness). Finally, Section 5 provides some concluding remarks.

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\* The financial support of MURST 60% is gratefully acknowledged. Thanks are due to an anonymous referee for comments and suggestions.

<sup>1</sup> We concentrate on the empirical evidence for the recent period of floating, 1973-90. The evidence for the 1920s seems to support the view that PPP then held (*cf.* FRENKEL, 1978; EDISON, 1985; TAYLOR and McMAHON, 1988 and ENDERS, 1989). A comprehensive survey of the empirical validity of PPP in the 1920s is to be found in OFFICER (1982).

### 1. Statement of the Alternative Versions of the Purchasing Power Parity Hypothesis

The strong or absolute version of PPP states that the equilibrium exchange rate between any two currencies ( $e$ ) equals the ratio between domestic and foreign prices (denoted by  $p$  and  $p^*$  respectively):

$$e = p/p^* \quad (1)$$

This version relies on the law of one price (LOP), according to which, abstracting from transportation costs, obstacles to trade and information costs, the price of a given good ( $i$ ), quoted in the same currency, will be the same in different locations:

$$p_i = ep_i \quad (2)$$

Equation (2) expresses the arbitrage condition. Departures from the arbitrage condition imply that there are profit opportunities. In a world of many commodities, however, the arbitrage condition alone does not ensure that PPP holds. A sufficient condition for the absolute version of PPP to prevail when the LOP holds for individual goods, is that the weight of each good in the aggregate price index is the same.<sup>2</sup> According to absolute PPP, the real exchange rate,  $q = (ep^*/p)$ , must always equal 1.

The weak version of PPP restates the theory allowing for obstacles to trade (such as tariffs and non-tariff barriers), transport costs, information costs, and market imperfections, under the assumption that they are constant over time:

$$e = k(p/p^*) \quad (3)$$

where  $k$  is a constant factor. This relation holds exactly in the rates of change, so that if the factors which cause absolute PPP to fail are constant over time, relative PPP might hold even when absolute PPP does not.<sup>3</sup> According to relative PPP, the real exchange rate is a constant.

<sup>2</sup> Let us consider a domestic price index  $p = f(p_1, p_2, \dots, p_n)$  and a foreign price index  $p^* = g(p_1^*, p_2^*, \dots, p_n^*)$ . Let  $p = \sum_i w_i p_i$  and  $p^* = \sum_i w_i^* p_i^*$ . If  $p_i = ep_i^*$ , then  $p^* = (\sum_i w_i^* p_i)/e$ . The PPP hypothesis requires that  $\sum_i w_i^* p_i = \sum_i w_i p_i$  or  $\sum_i (w_i^* - w_i) p_i = 0$ . If this condition is to hold for all possible sets of  $p_i$ s, then, given that  $p_i$ s are greater than 0, it is required that  $w_i^* = w_i$  for all  $i$ . If  $w_i$  is different from  $w_i^*$ , unless individual prices happen to take certain values such that  $\sum_i (w_i^* - w_i) p_i = 0$ , the domestic and foreign aggregate price indices will diverge.

<sup>3</sup> It must be noted, however, that relative PPP can be defined only with respect to the time period over which price levels and the exchange rate change, and that the choice

To state PPP in terms of expected prices gives rise to the so-called *ex ante* PPP. This version postulates that the expected change in the exchange rate fully matches the expected inflation differentials:<sup>4</sup>

$$E_{t-1}(\hat{e}_t) = E_{t-1}(\hat{p}_t - \hat{p}_t^*) \quad (4)$$

$E_{t-1}(\cdot)$  stands for the mathematical expectation of the variable in parentheses, conditional on the information available at time  $t-1$ . The *ex-ante* version of PPP relies on the efficient market hypothesis, according to which, since all the relevant information available at time  $t-1$  is reflected in the current exchange rate at time  $t$ , deviations from PPP should be serially uncorrelated (*cf.* Roll, 1979).

### 2. Sources of Departures from PPP: an Analytical Perspective

Departures from PPP are often observed (see below). According to their transitory or permanent nature, these departures have different implications for models based on the assumption that PPP holds. A number of factors have been suggested by different authors to justify deviations from PPP. Leaving aside problems such as trade barriers and different definitions of price indices in different countries, departures from PPP have been explained by referring to real shocks (such as productivity shocks, natural resource discovery and so on), different speeds of adjustment in goods and asset markets, departures from free competition, and product differentiation.

Real shocks have been used to justify persistent departures from long run equilibrium values, since they systematically influence the

of the base year is critical. If a base period for which PPP does not hold is chosen, problems of interpretations may arise. More specifically, to find that a change in the exchange rate is a fraction of the relative price change in two countries could paradoxically constitute positive evidence of a dynamic movement towards PPP and vice-versa, to find that the exchange rate movements offset completely changes in price levels could wrongly be interpreted as evidence in support of PPP. For similar reasons the choice of the terminal year is also important.

<sup>4</sup> More precisely, two versions of *ex ante* PPP have been proposed in the literature. That expressed by equation (4) is the less restrictive version. In its strong form this hypothesis assumes that real exchange rate changes are strictly zero.

relative price of traded and non traded goods within a country, and hence international relative price levels across countries and over time (*cf.* Begg, 1989).

Price stickiness, explained in turn by the presence of long term labour contracts combined with oligopolistic pricing in goods markets (Dunn, 1970; Dornbusch, 1987b), has instead been used to justify departures from PPP which are likely to be temporary (even though they can be permanent). Exchange rates are determined in asset markets, which clear faster than commodity markets and react quickly to "news"; prices, on the other hand, are determined in goods markets, and tend to adjust more slowly to the same "news" (*cf.* Dornbusch, 1987a, 1987b; Daniel, 1986b). Hence, "news" which causes an instantaneous adjustment of the exchange rates but not of prices could lead to temporary deviations from PPP. Over time, if or when commodity prices adjust, the deviations should diminish. However, to the extent that the supply and demand shocks are real, the discrepancy between adjustment of prices and exchange rates need not vanish (*i.e.* departures from PPP could be permanent).

Another possible explanation of departures from PPP recently put forward in the literature is based on the presence of uncertainty and sunk costs. These induce firms not to react promptly to exchange rate changes, but rather to assume a "wait and see" attitude (*cf.* Biasco, 1986; Krugman, 1989; Giovannetti, 1989). The resulting lack of arbitrage is likely to induce hysteresis (*i.e.* situations in which temporary shocks have effects that do not go away when the shocks no longer exist). It can also be noted that accumulation of net foreign debt may induce hysteresis, since a debtor country has to service the interest cost of the debt; hence, a transitory phase of trade deficit may require a permanent real exchange rate depreciation to ensure that the eventual long-run equilibrium has an adequate trade surplus for external balance (*cf.* Begg, 1989). In a situation where there is hysteresis, the long run equilibrium values of exchange rates and prices depend on the initial conditions and on the path that they follow in the short run (see Baldwin, 1988; Begg, 1989). Hence it is likely that PPP does not hold.

### 3. Empirical Problems

The empirical studies of the PPP hypothesis are likely to present a few common problems. These range from spurious regression to non-stationarity, from autoregression in the residuals to problems arising from differencing the data. In addition to these issues, there is also the choice of the appropriate price index to be used in the analysis, the choice between a multilateral and a bilateral approach and the problem of simultaneous determination of prices and exchange rates. We shall discuss below some of the major issues involved.

#### 3.1 Choice of the Price Index

The controversy over the choice of the price index is linked with theoretical considerations and with the debate about the forces that should act to correct purchasing power disparities. On one hand, authors who emphasise the role of commodity arbitrage to explain the PPP relationship (*cf.* Isard, 1977; Kravis and Lipsey, 1978; Milone, 1986) argue that an index of traded goods has to be used, and seem to consider that the relative price of tradables and non tradables remains constant. The choice here is between export prices and wholesale prices indices. In practice, wholesale prices are preferred because (i) export prices are generally measured as unit value indices and change when the composition of exports changes; (ii) they completely leave out the prices of import-competing goods.

On the other hand, authors who explain the PPP relationship by referring to different pricing mechanisms in goods and asset markets indicate that the proper index should cover the broadest range of commodities (*cf.* Frenkel, 1981a; Daniel, 1986a; Isard, 1977) and that the use of traded goods in a derivation of PPP amounts to nothing more than a tautology (*i.e.* the price of a bundle of domestic goods is the same as an identical bundle of foreign goods when converted into a common currency). However, if a price index which includes both traded and non traded goods is used, this can impart a bias into the calculation of PPP, stemming from cross-country differences in weight (*cf.* Officer, 1976 and 1982). The choice is, in this case, between the consumer price index (CPI) and the GDP deflator. The CPI "provides a partial rather than a comprehensive measure of

price level change" (Kravis and Lipsey, 1978, p. 200), while the GDP deflator "has the strongest claim to represent a general measure of a country's price level. It is based on a conceptual framework that assigns an appropriate weight to each good, whatever the classification chosen" (Kravis and Lipsey, 1978, pp. 199-200). Hence, when they are available, "the preference is most often given to GDP deflators that have a clear methodological definition" (Dornbusch, 1987b, p. 1079).<sup>5</sup>

### 3.2 Bilateral Versus Multilateral Approach

The choice between bilateral and multilateral models of exchange rates and prices in econometric tests of PPP can affect the results. The bilateral model ignores the large correlation that may exist between exchange rate movements and may therefore imply imprecise estimates. According to Hakkio (1984), a contemporaneous correlation of error terms in regressions of several currencies against some "base" country (e.g. USA) may exist because of world business cycle effects arising from world shocks and because of the base-country element. Hakkio's insight is that more precise estimates of slope coefficients can be obtained by exploiting the information about the cross-equations residuals correlation, *i.e.* by using the seemingly unrelated regression (SURE) method rather than ordinary least squares (OLS) equation by equation.

The problem of bilateral bias has also been dealt with by using an "effective exchange rate" – a weighted average of bilateral exchange rates, where the weights are represented by the share of trade of the country considered with respect to each region – and "effective" foreign price levels for each country, *i.e.* weighted price indices (*cf.* Officer, 1980). The rationale underlying the use of an effective exchange rate is that PPP is more likely to hold between major trading partners than between isolated countries.<sup>6</sup>

<sup>5</sup> RUSH and HUSTED (1985) object to the use of GDP deflators; they argue that "GDP deflators cover only prices of currently produced goods and services, while consumer price indices contain prices of second hand goods as well as currently produced items. Thus the argument in favour of the use of GDP deflators is not entirely one-sided, since CPI contains a class of goods omitted from the deflators" (p. 139). OFFICER (1982) also argues in favour of CPI, given that the GDP deflator is a current weighted index rather than a base weighted index and will therefore not reflect average price level changes.

<sup>6</sup> A new approach, based on Divisia index numbers has been recently developed by MANZUR (1990). This multi-country approach allows one to account for the effects of

In practice, the arbitrariness in the choice of trade weights for effective exchange rates and difficulties of estimation have led most authors to use the bilateral approach. Exceptions are Schotman (1987); Abuaf and Jorion (1990).

### 3.3 Non-stationarity of the Series

An assumption of the standard regression analysis is that series should be stationary. Stationary series show mean reverting behaviour (*i.e.* where the expected time between two crosses is finite), have a finite variance and a finite memory, in the sense that the effect of a shock today on their future evolution will eventually die out (*cf.* Granger, 1986 for a formal and complete definition). If any of the series used in empirical analyses is stochastic and non-stationary, tests based upon the classical assumptions are inappropriate (*cf.* Phillips, 1987). Prices and exchange rates seem to be non-stationary, when subjected to appropriate stationarity tests. Hence, the empirical studies which do not study the time series characteristics of exchange rates and prices may present inconsistent estimates of the relation between these two variables. Studies which have solved the problem of non-stationarity by using first differences may also present drawbacks, since transformation such as differencing may bias test procedures (*cf.* Fuller, 1976; Phillips, 1987) and regressions in first differences have little power against the alternative of a stable near random walk model (Dickey and Fuller, 1979). The non-stationarity issue calls for cointegration as an appropriate framework to test for PPP. Cointegration<sup>7</sup> allows one to exploit the non-stationarity of exchange rates and prices in order to make inferences about the long run properties of deviations from PPP. Stationarity of these deviations provides support for the hypothesis in the long run, allowing at the same time for short run departures. The consequences of cointe-

global shocks which might simultaneously hit a number of currencies and provide a test for PPP for each observation of the sample period (not only for the whole period as regression analysis). Manzur's study shows that PPP does not hold in the short run, while it seems to hold in the long run.

<sup>7</sup> This methodology (*cf.* ENGLE and GRANGER, 1987) states that two sequences of random variables are said to be cointegrated if:

- (a) they are non stationary in levels;
- (b) they are of the same order of integration, *i.e.* they need to be differenced the same number of times to become stationary;
- (c) there exists a linear combination of the level which is stationary.

gration of exchange rates and prices go beyond the issue of mean reverting behaviour of real exchange rates. When the variables in levels are cointegrated, in fact, simple first differencing in order to deal with non-stationarity induces econometric problems, since it is not possible to construct an autoregressive (AR) representation from the moving average (MA) model (*i.e.* the MA representation of the first differences is not invertible).

### 3.4 Problems of Simultaneity

It is possible that, in the context of the PPP hypothesis, both exchange rates and prices may be endogenous. This may lead to a simultaneous equations bias in the estimates. Krugman (1978), specifically addressing the issue of simultaneity, argues that PPP can be falsely rejected in models in which it is true, because the estimates of the price coefficient are biased towards zero. The problem can be dealt with empirically, in short run analyses, by using the instrumental variables (IV) method of estimation (*cf.* Frenkel, 1981b). Frenkel performs tests of causality in the sense of Granger. He suggests that the traditional formulation of empirical tests of PPP which views prices as causing exchange rates is not strictly supported by his data, and that a solution to the problem could be to use prices as the dependent variable and regress them on exchange rates (*cf.* also McNown and Wallace, 1990).

It is worth noting that the problem of simultaneity bias does not arise in the framework of cointegration. If prices and exchange rates are integrated of the same order and cointegrated, the low frequency components of the series will dominate the high frequency components in the cointegration regression and this allows one to abstract from the explicit consideration of "direction of causality". The correlation between the regressor and the error will, in fact, be of a lower order than the variance of the regressor itself (*cf.* Engle and Granger, 1987).

## 4. Recent Tests of the Empirical Validity of the PPP Hypothesis

The existing empirical evidence on PPP is mixed. It is now widely recognised that substantial departures from PPP are possible

in the short run. The results on the long run validity of the hypothesis are, however, controversial. Moreover, the evidence is sensitive to the choice of the country, time period, econometric technique and price indices. There are many different ways and techniques for testing PPP: econometric tests, case studies of particular industries and statistical analyses of sectoral data. The econometric tests, on which we shall concentrate, range from regression analysis to the study of time series properties of real exchange rates, and can be carried out at a micro or macro level (*i.e.* the arbitrage relationship for homogeneous tradable goods or the regressions of exchange rates on prices or vice-versa). Any classification entails a certain degree of arbitrariness. We are mainly interested in tests of the long run validity of PPP as an equilibrium condition, since long run PPP is still a building block of most models of exchange rate determination (*cf.* Dornbusch, 1976, 1987a). However, the studies which have specifically addressed the issue of the validity of PPP in the long run have been subject to major criticisms, primarily because of the *ad hoc* techniques often used in these studies. Regression analysis implicitly assumes the validity of a given model for cycles of high and low frequencies (and the short run variability tends to dominate). Therefore, regression analysis for long run purposes has to be applied to filtered data. The drawback is that this method completely disregards the short run movements in variables. Spectral analysis seems to be an appropriate framework for testing PPP in the long run, but it requires stationarity of the series. If the series are non-stationary, cointegration can represent an appropriate framework to test for PPP as a long run equilibrium condition. One has to be aware of the fact, however, that the unit roots tests which are used have a very low power and that if the unit roots tests lead to incorrect conclusions (*i.e.* it is assumed incorrectly that the series are integrated of order 1), then the cointegration tests of  $p$ ,  $p^*$  and  $e$  as a test of PPP holding in the long run will have zero power against the alternative that PPP does not hold.

### 4.1 The Short Run

#### 4.1.1 PPP as an Arbitrage Relationship

From a theoretical perspective, the view of PPP as an arbitrage condition is equivalent to what is commonly known as the law of one

price. If the law of one price is rejected, in general, the validity of PPP is questioned.<sup>8</sup> As mentioned before, however, the inverse relationship, is not true since, even if the law of one price holds, differences in price indices and weighting schemes can cause failure of PPP (*cf.* Katseli, 1979; Webster, 1987 and the previous discussion on weights in footnote 2).<sup>9</sup>

The empirical tests of the law of one price carried out in the last two decades have largely produced negative results: arbitrage does not seem to hold in the short run even for homogeneous tradable goods.<sup>10</sup> Kravis and Lipsey (1978) and Isard (1977) have shown that for the same good (or highly substitutable good) there were quite definitely persistent price discrepancies between domestic and foreign prices over the period 1971-1977. More recent studies by Webster (1987) and Milone (1986) also support the view that there is little evidence that complete arbitrage occurred in the period of floating exchange rates. Webster emphasises the fact that this could be due to the different speeds of adjustment of different industries to the stimulus of changing exchange rates and foreign prices.<sup>11</sup> His results (for UK versus US manufacturing industries) are not supportive of the PPP hypothesis; however, "this should not be interpreted as an argument to suggest that domestic prices are insensitive to both foreign prices and to exchange rates. Indeed the evidence of this study suggests a high degree of sensitivity. Prices, therefore, do

<sup>8</sup> With respect to the fact that validity of the law of one price does not imply PPP, BEGG (1989) considers the case of the UK in the early 1980s, when the real value of the sterling was above its "long-run equilibrium value". He argues: "if British exporters had applied conventional profit margins to domestic costs, they would not have been able to sell in foreign markets; they were uncompetitive. One strategy would have been to withdraw from such markets and wait for the exchange rate to come down. But there are big costs of breaking into markets. Many exporters decided to match foreign prices in order to keep selling (obeying the law of one price), even though in order to do so they had to sell at sterling prices which were below sterling costs of production. In short, looking at output prices we conclude that the law of one price held (approximately) but it gives the wrong signal about competitiveness when profit margins are varying" (p. 28). See also GIOVANNETTI (1989) for a detailed treatment.

<sup>9</sup> A very peculiar situation may arise where PPP holds and the law of one price does not, when a multilateral approach is adopted.

<sup>10</sup> Notice that as PPP is an arbitrage condition, it does not itself postulate which way the regression should be run. Usually the regression of exchange rates on relative prices has been used, but the reverse regression of prices on exchange rates is also compatible with PPP, *e.g.* KRUGMAN (1978).

<sup>11</sup> This fact also justifies the tests of the PPP relationship as an arbitrage condition. In fact, if the different industries have different speeds of adjustment to shocks, the aggregate price indices cannot capture any long-run adjustment process, and there is no point in testing aggregate relationships.

appear to respond to external stimuli but *not* in the manner that relative PPP suggests" (Webster, 1987, p. 1444). Milone tests whether percentage changes in the ratio of Italian to British prices of tyres and machinery (both expressed in domestic currency) matches the percentage changes in the exchange rate. He finds that in the 1970s the ratio of Italian to British prices tended to fall systematically, rather than to fluctuate around a stable value. Evidence in support of the LOP is, however, provided by Goodwin *et al.* (1990). They reformulate the LOP using rational price expectations on the grounds that, because of delivery lags, expected prices are to be preferred to current prices as explanatory variable. The expectation-augmented model provides stronger support than the conventional formulation.

#### 4.1.2 Tests of Variability of Real Exchange Rates

The recent literature on PPP has paid a great deal of attention to the real exchange rate ( $q$ ) on the ground that if PPP holds at all times, real exchange rates should be independent of the variations in nominal exchange rates (or other nominal variables).<sup>12</sup> If, on the contrary, there are factors other than relative prices driving exchange rates, the real and nominal exchange rates are not independent. A change in the real exchange rate, in fact, reflects a discrepancy between the rate of change of the nominal exchange rate and the difference between the domestic and foreign rate of inflation.

Variability of the real exchange rate in the short run has been mainly explained with reference to different pricing mechanisms for nominal exchange rates and prices and to the role of "news". News in this context is taken to mean any new information which is of relevance to the exchange rate and which was not anticipated in the previous period (*cf.* Dornbusch, 1976). Empirical support for the "news" hypothesis is provided by Daniel (1986b) who, using the USA as the "standard country"<sup>13</sup>, finds that, contrary to PPP prediction, the exchange rates of France, Germany and Japan versus the US dollar seem to follow a random walk, while the pound/US dollar exchange rate seems to follow a first order moving average process

<sup>12</sup> KATSELI (1984) discusses problems connected with the construction of indices of real exchange rates, *cf.* pp. 289 *ff.*; *cf.* also DE GRAUWE *et al.* (1985) pp. 2 *ff.*

<sup>13</sup> The choice of the "standard country" has been discussed extensively by OFFICER (1982). It is likely to affect the results of the tests; *cf.* FISHER and PARK (1991).

and the Canadian dollar/US dollar exchange rate a second order moving average process. The results are "consistent with the hypothesis that "news" is instantaneously incorporated into exchange rates and slowly incorporated into prices for all countries tested, except Canada" (Daniel, 1986b, p. 322). In fact, PPP deviations increase with current exchange rate surprises because exchange rates immediately incorporate new information while prices only adjust with lags. These results are supported by the findings of Fisher and Park (1991): "the adjustment to disequilibrium occurs in the market for foreign exchange, not in the market for goods. This is concrete evidence that goods prices are indeed stickier than asset prices" (p. 1477). However, over time, as prices adjust, PPP deviations tend to diminish. To the extent that the news reflects a real shock, which induces a relative price change, part of the initial PPP deviation persists. PPP deviations, in other words, could be expected to disappear in the long run only if all shocks were nominal. The two explanations – sticky prices and real factors – are non-competing, as they can explain deviations from PPP in the short run and in the long run respectively. The findings of Daniel (1986b) are in line with those of Frenkel (1981a), Dornbusch (1987b) and Saidi and Swoboda (1983). In addition, changes in nominal exchange rates seem to "dominate" movements in real exchange rates, contrary to what is implied by PPP, according to which the real exchange rate should be driven by movement in prices (*cf.* Baillie and McMahon, 1989).

## 4.2 The Long Run

### 4.2.1 Time Series Properties of Real Exchange Rates

Strictly linked with the studies of exchange rate variability are the analyses of the time series properties of real exchange rates. In fact, if movements in real exchange rates mirror those of nominal exchange rates and the latter approximately follow a random walk, it is not surprising that real exchange rates can also be approximated by the same model (*cf.* Roll, 1979; Adler and Lehmann, 1983; Hakkio, 1984; Mark, 1990). The inability to reject the random walk model for the real exchange rate provides evidence that PPP is violated in the long run, since real exchange rate innovations represent permanent changes.

The analysis of the time series properties of real exchange rates has often been used to test the *ex-ante* version of PPP (or efficient market version of PPP). This version, as we have seen above, states that all available information is used by market participants so that the expected rate of return (in real terms) is zero (otherwise a speculator could systematically make profits). It is worthwhile noting, from the literature on stock markets, that expected returns of different assets may differ as a result of differences in their riskiness rather than market inefficiency. Hence, as with other financial markets, any test of market efficiency for the foreign exchange market is a joint test of several composite hypotheses. It is impossible to develop a direct test of the hypothesis that the foreign exchange market is efficient. All that can be done is to present various statistical hypotheses regarding what one means by market efficiency and test these specifications by placing additional assumptions on the statistical properties of the data. Rejection of the null hypothesis is consequently not necessarily identified with market inefficiency. An immediate testable implication of the zero expected returns is that the real exchange rates are uncorrelated with their previous values. Thus, all the information about the future development of the exchange rate is included in the last period exchange rate. Adler and Lehmann (1983) find, using both monthly and annual data,<sup>14</sup> that the real exchange rates follow a martingale; their results are in line with Cumby and Obstfeld (1984), who argue that "the efficient market version of relative PPP has not characterised the recent experience with floating rates" (p. 146).

A different way to analyse the time series properties of real exchange rates is to study the spectra of bilateral real exchange rates (*cf.* De Grauwe *et al.*, 1985; Mussa, 1986). Spectral analysis allows the decomposition of the series of real exchange rates into cycles of different frequencies. The low frequency components are associated with long run variations and the high frequency components are associated with short term cyclical fluctuations. "The analysis in frequency domain ... centers the interest on the contributions made by

<sup>14</sup> The tests are replicated on the annual data because "if the real exchange rate followed a stable autoregressive process in monthly data, our test should reject the martingale model in annual data. Since our results in annual data provide the strongest evidence in favour of the martingale model, we have substantial evidence against the hypothesis of a stable but highly correlated autoregression in monthly data" (ADLER and LEHMANN, 1983, p. 1483).

the various periodic components in the explanations of the total variation of a given time series, *i.e.* it describes a stochastic process in terms of the relative importance of different kinds of oscillations that shape it" (Mecagni, 1986, p. 16). To apply spectral analysis, however, it is first necessary to test if the time series is stationary. De Grauwe *et al.* (1985) find that during the 1970s the level of real exchange rates of the major currencies (*i.e.* US dollar, German mark, French franc, UK pound, Japanese yen, Italian lira) were non-stationary in the mean and, hence, the series had to be adjusted before proceeding to spectral analysis. Mecagni (1986), using spectral analysis, argues that the frequency domain analysis does not support the PPP hypothesis in the long run (as the time domain analysis did not support it in the short run): "the hypothesis of an evolution of the slope coefficient toward the value required by PPP the more we restrict the estimation band toward low frequencies is largely not supported by the data ... A tendency, in some cases, for the point estimates to conform, in the long term periodicities, to the PPP value is in fact accompanied by increasing imprecision of the estimates, impeaching reliable hypothesis testing" (pp. 34-35).

#### 4.2.2 Regression Analysis and the Long Run

We said above that regression analysis tends to give more weight to cyclical fluctuations. In order to apply it to long run analysis it is possible to filter the data; otherwise some special conditions have to be satisfied. In order to extract the long run component of exchange rates and prices, Rush and Husted (1985) decompose the series  $P$  (logarithm of domestic price level) into a systematic part ( $S_{p,t}$ ) which follows an ARIMA process, and a white noise  $N_{p,t}$ , which embodies all the transient features. They then design a two-sided filter "optimally" to extract an estimate of  $S_{p,t}$  after having smoothed each series (the estimate is optimal in the sense that it minimises the variance of the estimated  $N_{p,t}$ ). After having filtered the data on prices and exchange rates, they estimate OLS regressions to test the validity of the PPP hypothesis. Their results are mixed and highly dependent on the choice of the base country. If the US is used as *numéraire*, the PPP hypothesis seems to hold in the long run, while if other countries are used, PPP is generally rejected. These mixed results lead them to argue that: "the mere fact that we are unable to accept unambiguously the presence of long-run PPP should lead to a little

discomfort on the part of the proponents of PPP and those who base policy on PPP, as well as theoretical economists who make PPP an assumption of their work" (p. 143).

More recently, in the context of regression analysis, the cointegration technique has been applied to the study of PPP as a long run equilibrium relationship. This technique allows one to study whether non-stationary exchange rates and prices are tied together in the long run. Cointegration allows one to account for the variability of the high frequency components, while concentrating on long run characteristics. Schotman (1987), Giovannetti (1987), Corbae and Ouliaris (1988), Edison and Klovland (1987), Enders (1988), Hakkio and Rush (1989), Taylor (1988), Mark (1990), Fisher and Park (1991) amongst others apply the cointegration technique to tests for the PPP hypothesis.<sup>15</sup> Broadly speaking, testing if nominal exchange rates and relative prices are cointegrated is the counterpart of stationarity tests on real exchange rates. If non-stationary prices and exchange rates are cointegrated, in fact, real exchange rates have to be stationary (the residuals from the PPP equation:  $z_t = \log(e_t) - \beta \log(p/p^*)_t$  coincide with the real exchange rates if the restriction  $\beta=1$  is imposed). However, cases may exist where two data series are cointegrated and the real exchange rate is stationary, but purchasing power parity fails to hold because the estimated cointegration parameter is significantly different from 1. These cases motivate the use of cointegration versus the strategy of simply examining the time series behaviour of the real exchange rate.

The evidence provided so far, using the cointegration technique to test the validity of the PPP hypothesis, does not seem to support the view of long run proportionality between exchange rates and prices.<sup>16</sup> Taylor (1988) obtains results "unfavourable to the PPP hypothesis. In particular, the exchange rate and relative prices did not appear to be cointegrated for any of the countries examined" (p. 1377). Giovannetti (1987) rejects the absolute version of PPP for the bilateral exchange rate of the dollar versus the currencies of the seven major industrialized countries. Corbae and Ouliaris (1988) are

<sup>15</sup> A study by TAYLOR and McMAHON (1988), using cointegration, is generally supportive of PPP in the long run for the 1920s. Some problems arise for the pound/dollar exchange rate. The authors claim that they are able to reconcile apparently conflicting evidence, *i.e.* deviations in the short run and tendency to an equilibrium level in the long run.

<sup>16</sup> Clearly the results depend on the different currencies tested, the different periods covered and they are all subject to the critique of low power of unit roots tests.



unable to reject the null hypothesis of a unit root for the real exchange rate and therefore reject the long run absolute version of PPP, and so do Hakkio and Rush (1989), who use cointegration to examine market efficiency. Mark (1990) examines bilateral relations using the US, the UK and Germany as "home countries" and provides evidence unfavourable to the hypothesis that PPP holds in the floating period 1973-88. Finally, an interesting study by Fisher and Park (1991) finds that a weak form of PPP describes the behaviour of almost all the major currencies *except* Canadian and American dollars. This leads the authors to conclude that "perhaps the fact that the US dollar is the key currency in the international monetary system has cut the link between its value and measures of inflation" (p. 1483).

## 5. Conclusion

This survey has focused on two major issues.

At the microeconomic level it has reviewed the empirical tests of the PPP relationship as an arbitrage (short run) condition, which are usually carried out through regression analysis.

At the macroeconomic level, the survey has examined studies of the developments of nominal exchange rates, prices and real exchange rates over time. The econometric methods used are different and depend on whether the emphasis is on the short or long run validity of the PPP relationship. Regression analysis and simple statistical techniques for testing the variability of real exchange rates are used in the short run. In the long run, regression analysis is used after having filtered the data of the short run variability (cyclical) or if it is found that non-stationary series are cointegrated. Again in the long run, the time series characteristics of real exchange rates are examined, either by simple stationarity tests or by using spectral analysis.

The evidence over the last two decades suggests that the law of one price does not hold, *i.e.* that perfect arbitrage does not occur. As far as the variability of exchange rates is concerned, there is agreement on the claim that it has been "excessive" (higher than the variability of nominal exchange rates); furthermore, real exchange

rates seem to be non-stationary and exchange rates and prices non-cointegrated. Hence, there is considerable empirical evidence rejecting the PPP hypothesis.

However, a number of criticisms can be levelled at the limits within which these tests are run:

- different industries may have different speeds of adjustment to shocks, in which case an aggregate price index may not be able to capture the long run adjustment process (*cf.* Webster, 1987), making a test for an aggregate relationship inappropriate.
- A period of 15-20 years may not be long enough to detect the mean reverting behaviour of exchange rates implied by PPP (*cf.* Frankel and Meese, 1988; Adler and Lehmann, 1983). The "true" long run may be more than 20 years. If this is the case, results unfavourable to PPP may simply be the result of data truncation. Extension of the data set backwards, however, would be inappropriate, as it is very difficult to deal with regime changes.<sup>17</sup>

These and the other problems reviewed in this survey show the pitfalls involved in carrying out a proper and reliable test for PPP. Given the fact that at the theoretical level the two main areas of research have concerned the rationality of assets markets (*cf.* Frankel and Meese, 1988) and the microeconomic effects of real exchange rate changes (*cf.* Krugman, 1989), a suggestion for future empirical research could be to study in detail the behaviour of markets and forget altogether about aggregate tests of purchasing power parity.

Rome

GIORGIA GIOVANNETTI

<sup>17</sup> It has been documented by MUSSA (1986) that the behaviour of real and nominal exchange rates has differed significantly across periods of fixed and nominal exchange rates regime and in particular that the variance is much larger under floating exchange rates.

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