PURCHASING POWER PARITY: EVIDENCE FROM UKRAINE

by

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Abstract

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This study analyses the validity of the purchasing power parity condition in Ukraine. For a long time researchers have been investigating the validity of PPP by testing whether the real exchange rates are stationary (or in extreme cases constant). In a univariate framework, PPP is very often rejected as an exact economic law. Nevertheless, investigation of half-lives (that is the time taken for a time series sequence to adjust halfway back to its initial level after a shock) could provide useful economic information and establish grounds for cross-currencies comparisons. For a country with relatively high inflation like Ukraine one might expect more evidence in support of PPP if the latter works through monetary channels. On the other hand, Ukraine has an evident disadvantage for empirical work of an extremely short sample period. To overcome this problem I use a specification based on the Im-Pesaran-Shin panel unit root test developed recently. Thus, this paper is an attempt to test whether the real exchange rates in Ukraine adjust to some long-run level, or whether the purchasing power concept is completely inapplicable in the transition country case. The results of univariate and multivariate tests are then compared with the case when USD is used as a numeraire currency over the same sample, and with other results reported in the literature. On the basis of the empirical investigation conclusions are reached concerning the validity of PPP in Ukraine.

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GLOSSARY

The law of one price. In the absence of any frictions the price of a good is the same in all locations if it is quoted in the same currency (Dornbusch 2002, p. 1076)

Purchasing power parity. A theory of exchange rate determination assuming that the exchange rate *change* between two currencies is determined by relative price level *changes* (Dornbusch 2002, p. 1075)

Half-life to convergence. Period of time t required for the expected value of a sequence $\{q_t\}$, which follows stationary AR (p) process, to revert half of its initial post-shock value (Mark 2001, p. 32)

Chapter 1

INTRODUCTION

Money and prices are probably the most exciting economic categories to ordinary people. It is not surprising that the value of money, as reflected in its purchasing power, has been in the focus of economists' attention for a long time. The relationship between an exchange rate and the purchasing power of different monies, which is considered in this work, is an interesting application of the concept to the international arena. If an exchange rate reflects the true relationship between purchasing powers of currencies in two countries, then it should reflect price level changes in these countries. This simple idea of *purchasing power parity* has been extremely popular in theoretical and empirical investigations for a long time.

Being one of the oldest concepts still used in modern international economics with its roots going as far back as XVI-early XVII century, the PPP concept has, in different periods of time, captured the attention of such major economists as David Ricardo, John Maynard Keynes and Paul Samuelson. Even today the PPP relations can be used as a rough guide to determine how the exchange rates may adjust in response to price level changes. Given the extensive literature that considers the validity of PPP for developed economies, it is quite surprising how little research has been done in this area for transition economies. This observation motivates this analysis of PPP applied to the case of Ukraine.

One of the possible explanations for this lack of empirical studies of transition economies lies in econometric problems surrounding PPP testing. As Froot and

Rogoff (1995, p. 1648) point out: "A decade ago[1] … PPP seemed like a fairly dull research topic." The authors explain that, on the one hand, floating exchange rates made it evident that PPP is not a short-run concept and, on the other hand, the tests of PPP in the long run were not possible in the absence of long enough time spans and the availability of appropriate econometric techniques (Froot and Rogoff 1995, p. 1649). As my further analysis shows some of these statements are applicable to the Ukrainian case. Although the strict PPP condition is often violated in Ukraine in the short-run and it is virtually impossible to extend significantly the sample period, there are at least two ways to extract useful economic information from PPP testing with respect to Ukrainian real exchange rates. One way is to study whether PPP holds in the long run and how "long" is this long run (keeping in mind the famous statement attributed to Keynes that in the long run we are all dead!). Calculating half-lives to convergence provides a good proxy for a speed of long-run adjustment. Even if PPP does not hold in the short run but the real exchange rates adjust to some long-run values relatively quickly, then the purchasing parity concept is still useful and applicable in economic analysis. Another recently developed alternative is to use panel unit root tests, which allow one to increase the power of the tests. One may expect better results for PPP tests (for example, shorter half-lives) for transition *compared with* developed economies estimated over *the same* sample period. These better anticipated results for the transition economies come from the impact of the relatively high inflation most of these countries experienced - a condition, which usually gives the most supportive results in parity tests (Froot and Rogoff 1995).

The question of whether *real* exchange rates among countries adjust to some long-run value (that is how PPP is usually tested in modern applications) is very important from both a theoretical and practical point of view. Empirical testing of the purchasing power parity hypotheses could provide justification for using

[1] Published in 1995.

existent theories of international finance for describing real economy *or* call for some additional investigation. Moreover, results of such tests have important policy implications for a transition economy like Ukraine. For example, the relationship between the real exchange rate and inflation is important, because the governments in transition countries often use the exchange rate as policy anchor in their stabilization programs. Mark (2001, p. 163) presents an excellent discussion of important policy implications of testing the long run validity of PPP. A prolonged real appreciation of a currency may undermine international competitiveness of the country but can apparently benefit the consumers. On the contrary, a real depreciation may be beneficial to tradable industries but harmful to consumers[2] (Mark 2001, p.163). An additional problem noted by Mark (2001, p.163) is that of the foreign debt of developing countries, which is often denominated in US dollars. A real depreciation relative to the US dollar then causes a real increase in costs of debt servicing.

Of course, tests of PPP in the transition country case have possible limitations because of restrictions on free trade and capital mobility. Specifically, in Ukraine, PPP might not work due to its managed (rather than fully) floating exchange rate regime and currency interventions of the National Bank of Ukraine, attempting to keep the exchange rate of the hryvna stable. In addition to currency restrictions there are numerous tariff and non-tariff barriers to free trade, which may prevent PPP from holding in Ukraine. However, the purpose of this work is not to test whether PPP works as an exact economic law but rather to find out how "real" is the real exchange rate – that is to examine if there are any prolonged and significant deviations from a steady long run value of the real exchange rate. With these considerations in mind in mind I conduct this study of evidence relating to PPP for Ukraine.

[2] Of course, real depreciation might not be a good policy to enhance competitiveness due to possible inflation as a result of increase in prices of imported goods.

Chapter 2

EVIDENCE ON PURCHASING PARITY RELATIONS: A SURVEY OF LITERATURE

Given the exceptional importance and attention devoted to purchasing power parity concept it is not surprising that it has been widely tested and included in economics textbooks, articles and working papers.

Although the concept of PPP is by no means a new one[3] it is still used in models of international economics. In the absolute version of PPP, in equilibrium, the spot exchange rate between two countries S (units of domestic currency for a unit of a foreign currency) is equal to the ratio of general price levels of two countries P and P* (for domestic and foreign price levels respectively). The relative version of PPP implies that in the presence of obstacles to trade increase in the home price level relative to the foreign price level leads to proportional depreciation of the home currency: $\hat{S} = \hat{P} - \hat{P}^*$, where a ^ stands for a percentage change (Dornbusch 2002). There are some major problems with testing PPP such as constructing price indices (should one incorporate traded goods only or both traded and non-traded goods) and period of testing (the short run or the long run). Mark (2001, p. 63) distinguishes two approaches to PPP testing based on consumer or producer price indices. Historically, the first approach is attributed to the Swedish economist Gustav Cassel who in 1918 coined the term "purchasing power parity" (Dornbusch 2002). The Casselian view on PPP is tested based on consumer price indices because in this view the nominal exchange rate should reflect relative purchasing powers measured by overall price

[3] The idea of PPP concept originated from 16th century Spain and early 17th century England. For extensive discussion of history of the PPP concept see, for example, Dornbusch (2002).

levels in trading countries. (Mark 2001, p. 63). On the contrary, more recent commodity-arbitrage view of PPP, attributed to Samuelson (1964) says that the law of one price should hold for goods that are traded internationally (Mark 2001, p. 63):

> "It can be argued that the production price index (PPI) is a better choice for studying PPP, since it is more heavily weighted toward tradable goods than CPI, which includes items such as housing services which do not trade internationally."

Another important distinction in PPP testing is its validity in the short-run or the long run. Even though PPP is often rejected in the short-run it still can be used to determine the speed of adjustment of a real exchange rate to some long-run value, for example by estimating half-lives.

In addition to these problems a number of purely theoretical drawbacks might undermine the validity of the PPP concept. Among these are the existence of trade barriers, transport and information costs, the notion of real *versus* monetary disturbances studied by Samuelson and Officer, the issue of different productivity levels in traded compared with non-traded sectors raised by Balassa, and other claims, a thorough discussion of which is clearly beyond the scope of this review[4].

Nevertheless, as Froot and Rogoff (1995, p. 1648) point out:

> "… the past decade has witnessed a tremendous degree of progress in the area and, in spite of some mis-steps and research tangents, several important results have emerged".

[4] An interested reader may refer to PPP surveys such as Froot and Rogoff (1995) or Gibson (1996).

Froot and Rogoff (1995) define three major stages in PPP testing: simple PPP as the null hypothesis, a random walk in the real exchange rates, and cointegration methods.[5]

In the first stage researchers were interested in testing if β is equal to one in the regressions of the form: $s_t = \alpha + \beta(p_t - p_t^*) + \varepsilon_t$, where s_t is the log of real exchange rate, α is a constant, p and p^* are the logs of domestic and foreign price levels and ε_t is the error term. Estimates of β where far from one (except for hyperinflationary economies) suggesting that PPP in this form fails (Froot and Rogoff 1995). Additional problem with this type of PPP testing is in possible non-stationarity of series used, which might undermine the validity of conventional statistical procedures.

Cointegration methods were the novel feature in testing PPP. Gibson (1996) reports four studies based on testing the following equation: $s_t = \beta p_t + \beta^* p^*_t + \zeta_t$ (lower case letters denote natural logarithms). For PPP hypothesis to hold the exchange rate, domestic and foreign prices must be cointegrated and $\beta=\beta^*=1$. The results are mixed for two earlier studies. For instance, Patel (1990) reports a PPP relation for five out of fifteen considered country pairs.

Two later studies by Kugler and Lenz (1993) and MacDonald (1993) use multivariate cointegration techniques, in which a test of a hypothesis that $\beta=\beta^*=1$ is conducted together with testing for cointegration (Gibson 1996). Kugler and Lenz (1993) use monthly data on the DM *vis-à-vis* 15 major currencies and find that PPP seems to hold for 6 European currencies in the long-run but does not hold for other (for example, U.S. and Canadian dollar). Similar mixed results are presented in MacDonald (1993). Absolute PPP receives almost no

[5] For the purposes of this study I survey stages in different order so that random walk stage is considered the last (and in the most extensive way).

support for USD *vis-à-vis* 5 major currencies in MacDonald (1993) study, although relative PPP seems to hold for the period from January 1974 to June 1990.

Earlier empirical studies of the properties of the real exchange rate in a univariate framework do not find much support in favor of PPP. Gibson (1996) gives a long list of empirical studies of PPP, which are in general unfavorable for the validity of the concept. For example, Cumby and Obstfeld (1982) decisively reject the hypothesis that *ex ante* PPP holds for 6 countries (U.S., U.K., Germany, Switzerland, Canada, Japan) from September 1975 to May 1981.

Recent studies have found much more evidence for the PPP concept, which could be explained by the increased time span of floating exchange rate regime and to a greater extent by advances in panel unit root testing.

Lothian and Taylor (1996) is probably the most often cited study of PPP testing over the long time span. Their annual data set for dollar-sterling and franc-sterling real exchange rates includes two centuries. Lothian and Taylor (1996) claim that simple stationary autoregressive models can explain up to 60-80 percent of in-sample variation in real exchange rates. At the same time, the mean-reversion is slow with estimated half-lives of 3 and 6 years for franc-sterling and dollar-sterling real exchange rates respectively. Lothian and Taylor (1996, p. 595) conclude in their discussion of the equilibrium properties of PPP that:

> "In the long run it remains a useful empirical first approximation. … Translated to the level of economic policy, these findings reinforce the idea of PPP as a long-run constraint."

Rogoff (1996) formulates the "purchasing power parity puzzle" with respect to relatively long half-lives of 3-5 years (reported in Lothian and Taylor (1996) and other studies). The puzzle is: how to reconcile the extreme short-term volatility of real exchange rates and slow damping out of shocks? Rogoff's (1996, p. 665) solution to the puzzle is somewhat pessimistic regarding PPP prospects:

> "As a consequence of various adjustment costs, there is a large buffer within which nominal exchange rates can move without producing an immediate proportional response in relative domestic prices."

Murray and Papell (2002) criticize Rogoff's (1996) PPP puzzle in their recent paper. The authors claim that Rogoff's conclusions are based on studies that did not control for serial correlation, did not include confidence intervals, and are based on biased estimates.[6] Murray and Papell (2002) conclude that although point estimates of half-lives are consistent with Rogoff's (1996), the confidence intervals are too wide to be informative in any sense. In the authors' view almost anything (starting from models with nominal rigidities up to models with rejection of PPP) is consistent with estimated confidence intervals.

Several important studies tested PPP in a multivariate framework in 90th. Jorion and Sweeney (1996) test stationarity of the real exchange rates as autoregressions of the logarithm of the real exchange rate in a multivariate framework for the Group of Ten plus Switzerland over the 1973-1993 flexible exchange rate period. The authors for the first time in literature report strong rejections of the null of a unit root in the real exchange rates for these currencies against the USD over the sample period. The rejection of a unit root is even more conclusive for the real exchange rate of European currencies versus DM. Jorion and Sweeney (1996) relate this result to limited exchange rate movements of European Monetary System currencies and geographical proximity of the European countries.

Papell and Theodoridis (1998) consider real exchange rates for 21 industrialised countries versus USD and DM over the period I.1973-IV.1996. The authors explicitly test the claim that PPP evidence is strengthening as time passes and more data become available. By varying length of sample period in the range

[6] In my analysis I try to control for small sample bias with the help of Kendall's (1954) formula. Murray and Papell (2002, p. 18) consider biased estimates as the major problem in studies used by Rogoff (1996).

from 1973-1982 to 1973-1996 they indeed find stronger evidence of PPP against the unit root as the span of the data becomes larger, but only for panel data methods[7]. However, this is not the case for univariate unit root tests with either the dollar or the mark used as a base currency. The problem of low power in this study is overcome by cross-section variation in order to increase power of the unit root tests over the relatively short 24-year-period.

In a similar way to Jorion and Sweeney (1996), Papell and Theodoridis (1998) find stronger evidence for PPP to hold when DM is used as a base currency compared with USD as a base (although even for the dollar it is strengthening over time). Their results reflect sharp rise and fall of the USD in the early 1980s.

Another panel data study of PPP is Koedijk, Schotman and Van Dijk (1998), who deal with 17 currencies between I.1972 and III.1996. The authors test PPP using a panel data methodology that is invariant to the choice of a numeraire currency, thus controlling for possible cross-sectional dependence. This methodology allows the authors to identify currency pairs for which PPP does or does not hold. The authors find that PPP holds for many currencies but not for every currency to the same extent and again with much stronger evidence when DM is used as a base compared with USD. Thus, Koedijk et al. (1998) find that the choice of a base currency is crucial in PPP research.

Apart from extensive empirical literature concerning PPP, there has also been great progress in the theory of panel unit root tests with application to real exchange rates in the 1990s. Given the exceptional importance of panel methods in modern econometrics it is not surprising that PPP testing is not left without attention. Mark (2001) considers three recently developed panel unit root tests developed by Levin and Lin (1993), Im, Pesaran and Shin (2002) and Maddala

[7] However, the rejections of a unit root do not increase monotonically with the sample size increase.

and Wu (1999)[8]. The evident advantage of the panel unit root tests is in their higher power in rejecting the unit root null in real exchange rates. The application of these tests to the data may lead to the consensus in the tests of PPP validity. However, Mark (2001, p. 48) argues that the mixed panels, cross-sectional dependence and small sample distortion are potential pitfalls in panel unit root tests.

Empirical studies of PPP discussed above have a lot of potential problems, but recent findings are consistent with the Froot and Rogoff (1995, p. 1683) claim that:

> "… research on parity purchasing power parity has enjoyed a rebirth" and "… there does seem to be long-run convergence to PPP, though further work on the issue of survivorship bias would be valuable".

[8] Description of these tests is provided in the methodological part of the work.

Chapter 3

METHODOLOGICAL ASPECTS OF TESTING PURCHASING POWER PARITY

In this chapter I will present methodology and testable hypothesis for the purchasing power parity (PPP). There have been basically three stages in testing for the purchasing power parity as outlined in Froot and Rogoff (1995). The first stage is based on testing regressions of the following form

$$s_t = \alpha + \beta(p_t - p_t^*) + \varepsilon_t, \qquad (3.1)$$

where s_t is the log of nominal exchange rate, α is a constant, p and p^* are the logs of domestic and foreign price levels and ε_t is the error term. The researchers in the first stage were mainly interested in testing whether β is close to one. In the second stage of PPP testing the emphasis is made on the properties of the log of real exchange rate *rx:*

$$rx_t = s_t - (p_t - p_t^*) \qquad (3.2)$$

In this setting PPP is assumed to hold if the log of real exchange rate rx_t is stationary.

The third stage deals with univariate and multivariate cointegration tests of PPP. These tests ask whether

$$s_t - (\mu p_t - \mu^* p_t^*) \qquad (3.3)$$

is stationary for any constant μ and μ^*.

Since the series of the log nominal exchange rates and prices are often nonstationary I will concentrate in my study on the properties of the real exchange rates (in univariate and multivariate frameworks) and to the lesser extent on cointegration methods.

The tests for a unit root null in the real exchange rates are usually performed with the help of the ADF type equation in the following form (Charemza and Deadman 1997, p. 104):

$$\Delta y_t = \delta y_{t-1} + \sum_{i=1}^{k} \delta_i \Delta y_{t-i} + \varepsilon_t , \qquad (3.4)$$

where the difference of variable y_t is regressed on lagged y_{t-1} and on $\Delta\, y_{t-i}$ to account for possible autocorrelation of order k in the error term ε_t. If the null hypothesis $\delta = 0$ is rejected in favour of the alternative $\delta < 0$ then the series is stationary. The ratio of δ to its standard error does not have the conventional t-ratio distribution and the decision rule is based on the critical values of Dickey-Fuller test statistics. The null of non-stationarity is rejected if the estimated value is less than corresponding critical value.

Another widely used alternative is the Phillips-Perron test, which is a nonparametric way of controlling for serial correlation when testing for stationarity.

Charemza and Deadman (1997) consider also one of the unit root tests developed by Perron (1989) for series with a possible structural break.

The 'additive outlier' test has as the null hypothesis a non-stationary stochastic process with a single pulse intervention at a known date $t = b$ (Charemza and Deadman 1997, p. 120):

$$H_0 : y_t = \mu + \gamma P_t + y_{t-1} + \varepsilon_t , \qquad (3.5)$$

where

$$P_t = \begin{cases} 1 & if \quad t = b \\ 0 & otherwise \end{cases},$$

The alternative hypothesis is a stationary process with a shift to a permanently higher mean at the same time $t = b$:

$$H_1 : y_t = \mu + \delta S_t + \varepsilon_t , \qquad (3.6)$$

where

$$S_t = \begin{cases} 1 & if \quad t \geq b \\ 0 & otherwise \end{cases} .$$

The test is performed in the following way. The residuals of the ordinary least squares regression under the alternative hypothesis are computed as:

$$\varepsilon_t = y_t - \tilde{\mu} - \tilde{\delta} S_{t,} \qquad (3.7)$$

where $\tilde{\mu}$ and $\hat{\delta}$ are the OLS estimates of μ and δ. In order to test the series for stationarity the residuals computed in the first stage are then used in the second stage equation:

$$\Delta\varepsilon_t = \omega P_t + \alpha^* \varepsilon_{t-1} + \nu_t, \qquad (3.8)$$

where $\alpha^* = \alpha - 1$ and ν_t is an error term. The test for stationarity is then testing whether the estimates of α^* is significantly negative based on critical values reported in Charemza and Deadman (1997).

Tests of PPP in the univariate framework often reject this hypothesis as exact economic law. Specifically, a unit root in the real exchange rates is usually not rejected. Even in this case though, it is still possible to extract some useful information from the data, for example by estimating the half-life to convergence.

Mark (2001, p. 32) derives the following expression for half-lives. Let the sequence {qt} follows the stationary AR (1) process $q_t=\rho q_{t-1}+ \varepsilon_t$ with unconditional mean equal to zero. Set $q_0=0$, then $q_1=\varepsilon_1$ and $E_1(q_t)=\rho^t q_1= \rho^t\varepsilon_1$. The half-life t is then the time needed for the expected value of q_t to revert to its initial value after shock of size: $E_1(q_t)= \varepsilon_1/2$. So $\rho^{t^*}\varepsilon_1=\varepsilon_1/2$ and the half-life is (Mark 2001, p. 32):

$$t^* = -\frac{\ln(2)}{\ln(\rho)} \qquad (3.9)$$

As Mark (2001, p. 32) notices this equation gives only an approximate half-life if $\{q_t\}$ follows higher-order serial correlation, but researchers still use it.

Before calculating half-lives it makes sense to adjust OLS estimates of ρ since they will be downward biased in small samples.

Kendall (1954) shows that least squares estimator has a bias equal to:

$$E(\rho^*) - \rho \cong -(1+3\cdot\rho)/T\,, \qquad (3.10)$$

where T is the number of observations.

From this one can calculate the bias-adjusted ρ as:

$$\rho^* = \frac{T\cdot\rho + 1}{T-3} \qquad (3.11)$$

The most recent developments in the area of purchasing parity concepts are aimed at increasing the power of the unit root tests with the help of panel data methods. Mark (2001) considers three panel unit root tests developed recently by Levin and Lin (1993), Im, Pesaran and Shin (2002) and Maddala and Wu (1999). For the purposes of this study, I consider only the Im-Pesaran-Shin test because the Levin-Lin test has too restrictive an alternative hypothesis and the Maddala-Wu test is derived under some binding statistical assumptions (Mark 2001). As Mark (2001, p. 46) shows the Im-Pesaran-Shin and Maddala-Wu tests relax the homogeneity restriction of the alternative hypothesis. The null and alternative hypotheses are:

$$H_0 : \beta_1 = \cdots = \beta_N = \beta = 0,$$

$$H_a : \beta_1 < 0 \cup \beta_2 < 0 \cdots \cup \beta_N < 0\,.$$

On the contrary, Levin-Lin test imposes a restriction that the β_i's are identical across individuals under both the null and alternative hypotheses (Mark 2001, p. 47). Mark (2001, p. 46-47) presents the following formulation of the Im-Pesaran-

Shin test (IPS test) with application to real exchange rates. Let individual *i* have the following ADF representation:

$$\Delta\tilde{q}_{it} = \alpha_i + \delta_i t + \beta_i \tilde{q}_{it-1} + \sum_{j=1}^{k_i} \phi_{ij} \Delta\tilde{q}_{it-j} + \varepsilon_{it}, \qquad (3.12)$$

where $E(\varepsilon_{it}\varepsilon_{js})=0$, $i \neq j$, for any t,s. It is also possible to remove a common time effect and analyze the deviations from the cross-sectional means: $\tilde{q}_{it} = q_{it} - (1/N)\sum_{i=1}^{N} \tau_i$. The potential problem with removing common time effect is in rejecting the true unit root hypothesis. However, as Mark (2001, p. 41) argues:

> "Subtracting off the cross-sectional average is not necessarily a fatal flaw in the procedure … because you are subtracting off only one potential unit root from each of the N time series."

Denote by τ_i the Studentized coefficient from the ADF regression and assume independent errors ε_{it} across individuals such that τ_i are also independent. Then by the central limit theorem:

$$\tilde{\tau}_{NT} = \frac{1}{N}\sum_{i=1}^{N} \tau_i \qquad (3.13)$$

converges to the standard normal distribution, first as $T \to \infty$ and then as $N \to \infty$ (Mark 2001, p. 46). Im, Pesaran and Shin (2002) report asymptotic critical values of the test statistic for DF regressions with constant and constant and trend included.

As the further analysis will show one can totally agree with the following statement (Mark 2001, p. 164):

> "The research on real exchange rate behaviour raises many questions but … offers few concrete answers".

Chapter 4

DATA DESCRIPTION

The purchasing power parity is tested using nominal exchange rates and inflation rates (wholesale price index or consumer price index). The data are available from International Monetary Fund. As such they are relatively reliable in terms of their cross-country comparability.

The validity of PPP in Ukrainian real exchange rates is tested against 16 transition economies and developed countries.

The sample period includes monthly observations starting from January 1996 to September 2002. The data are also available for the period starting from December 1992, but it was excluded from the sample (except otherwise noted) because the data for the earlier years of Ukrainian transition are not reliable due to reasons related to state formation. For example, the official exchange rate was often significantly lower than actual "black market" rate[9].

Most of the series are downloaded from IMF International Financial Statistics website and to the lesser extent from the official website of the National Bank of Ukraine. Detailed description of the data and their sources is provided in Appendix A.

[9] Another possible issue is the currency reform of September 1996. This problem is of lesser importance because the reform was not confiscating (It was announced and, thus, anticipated). Ukrainian exchange rates per USD available from the IMF website bear the note "that original data value is not to be overlaid with subsequent calculated data" for observations before 09.2003. To be on the safe side, only the data for January 1996 onwards are used for estimation because they are also available (and comparable) from the National Bank of Ukraine official website.

The nominal exchange rates are calculated as cross-rates based on the end of period exchange rates of currencies per USD (line *ae* in IMF International Financial Statistics web-site unless otherwise noted), which is usually used in the empirical literature as a numeraire currency. Nominal exchange rates for Russia are not available from the IFS website for the whole sample period. Thus, the hryvna - ruble nominal exchange rates are downloaded from the official website of the National Bank of Ukraine.

In line with empirical literature that considers commodity-arbitrage view of PPP, I use a wholesale price index (WPI or producer price index - line 63 in IMF International Financial Statistics web-site) unless otherwise noted as a proxy for inflation. Wholesale price indices incorporate a lower proportion of non-traded goods than consumer prices and generally give better results in empirical testing of PPP (Froot and Rogoff 1995).

Chapter 5

EMPIRICAL RESULTS

5.1. Testing for stationarity of the real exchange rates in a univariate framework

Before applying more advanced econometric techniques I would like to start from a single equation test of PPP as in equation (3.2) presented in the methodological section:

$$rx = s - (p - p),$$

where rx is the log of real exchange rate, s is the log of nominal exchange rate, p is the log of domestic price level, p^* is the log of foreign price level. An illustration of the real exchange rates for Ukraine versus a number of developed and transition economies is presented in Figure 5.1. The figure shows an upward spike in the real exchange rates (the real depreciation of Ukrainian currency) in the second half of 1998 (the period of Asian financial crisis) for all countries considered except for Russia. Apart from that break, all real exchange rates are relatively stable over the sample period and show adjustment to some long-run values. The general idea behind single equation models is to test for stationarity of the log real exchange rate as calculated in the equation above. In the case of bilateral PPP the null of non-stationarity should be rejected. The unit root analysis in a univariate framework is based on the Augmented Dickey-Fuller and Phillips-Perron tests[10].

[10] The estimation is done with the help of the Gauss program ppp1.pgm by Professor N. Mark from Ohio State University downloaded from his website (refer to Appendix B for details).

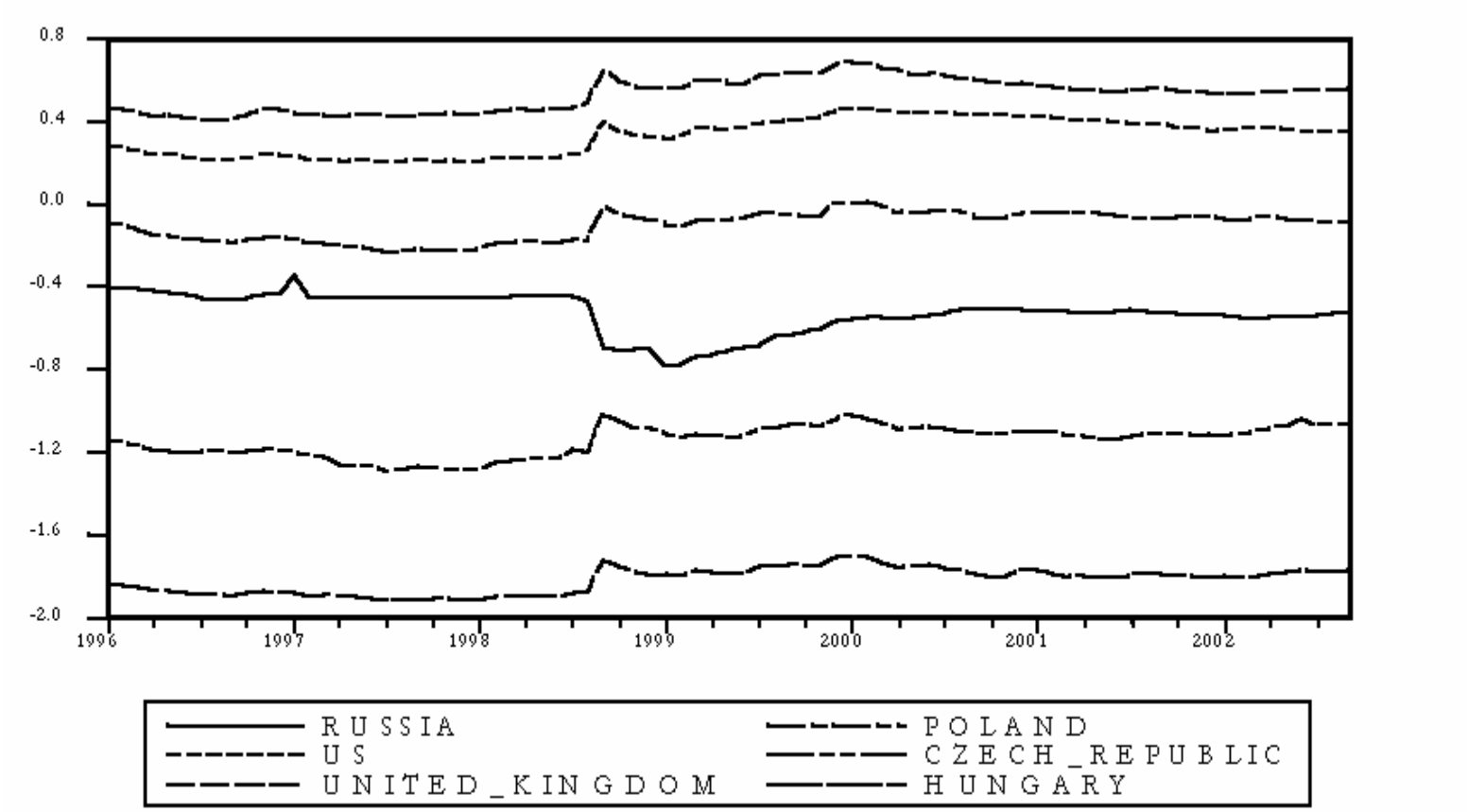

Figure 5.1 The log of real exchange rates for Ukraine

The results of the ADF and PP tests almost never reject the unit root null in Ukrainian real exchange rates and are reported in Tables 5.1-5.2[11]. This finding is not surprising given that only 7 years of data are available for Ukraine[12]. Similar results are reported in the literature. For example, Mark reports very comparable p-values for US and Germany using 25 (!) years of data (1973.I-1997.IV) which are presented in Appendix C3.

The analysis has shown that PPP is violated in the short-run for Ukrainian real exchange rates. One possible explanation for the short-run violation of PPP in Ukraine is relatively low inflation over the sample period. Indeed, for the period from 1996.01 to 2002.09 wholesale prices rose by only 14.6% per year. On the other hand, the short-run violation of PPP in Ukraine could have been expected because of low power of unit root tests. This is well documented in the economics literature. Mark (2001, p. 171) provides a very interesting distinction between statistical and economic significance with respect to PPP testing. With a sufficiently long time-series it might be possible to find statistically significant coefficients to reject a unit root. But if the value of root is 0.98 the half-life of a shock will be over 34 years and this stationary process may not be distinguishable from a true unit root in any meaningful economic sense (Mark 2001, p. 171). Furthermore, as Mark (2001, p. 171) argues:

> "If that is indeed the case, then in light of the statistical difficulties surrounding unit-root tests, it can be argued that we should not even care whether the real exchange rate has a unit root, but we should instead focus on measuring the economic implications of the real exchange rate's

[11]The p-values of ADF tests are presented in Appendix C1.

[12] When the sample period for Ukraine is only slightly extended to include observations starting from 1994.06 the results improve considerably (see Appendix C2). This is especially the case for Phillips-Perron test when the unit root null is rejected in Ukrainian real exchange rates in 9 (with constant) and 6 (with constant and trend) cases out of 16. Thus the unit root tests performed are robust to extending the sample period and in accordance with expectations provide more evidence in support of PPP even in the short-run. However, these results should be taken only as auxiliary evidence due to possible problems with data caused by state formation (as outlined in the data description).

behaviour. What market participants care about is the degree of persistence in the real exchange rate and one measure of persistence is half-life."

Even though PPP appears in general to be violated in the short-run for Ukrainian real exchange rates, it still makes sense to find the speed of long-run adjustment by calculating half-lives – to see how much time it takes to half recover the disturbance to equilibrium from the shock. For comparison, I report half-lives relative to USD and Ukraine over the same sample period (1996.01-2002.09) in Tables 5.1-5.2.

There are some interesting and meaningful inferences from the half-life estimates, which can be intuitively explained as follows. Although PPP is violated in Ukraine in the short run, the estimated half-lives show relatively quick adjustment to long-run values of real exchange rates. For instance, ADF tests give the half-life estimates of 1-2 years with trend and less than 1 year with trend and constant included into specification. Including a trend into the specification (for both ADF and PP tests) in general gives shorter half-lives pointing to possible trends in real exchange rates.

Another important finding is that there is no much difference in the results of PPP testing (except for PP tests with constant and trend) with Ukraine or United States used as numeraire. This is not surprising given that the hyperinflationary period in Ukraine before 1996 was excluded from the sample in order to obtain the most robust results. Due to the macroeconomic stabilization programme in the Ukraine, with average inflation in producer prices of 14,6% per year, the speed of long-run adjustment (measured by half-lives) is comparable with the speed of adjustment in US real exchange rates.

Table 5.1 The results of Augmented Dickey-Fuller tests for a unit root in the real exchange rates (12 lags included)

	Relative to Ukraine				*Relative to US*			
Country	ADF C	ρ	Adj. ρ	Half-live	ADF C	ρ	Adj. ρ	Half-live
US/UKRAINE	-1.794	0.944	0.993	8.377	-1.784	0.944	0.993	8.377
RUSSIA	-2.687	0.848	0.893	0.513	-2.066	0.910	0.958	1.340
ROMANIA	-2.420	0.874	0.920	0.697	-3.078	0.646	0.684	0.152
POLAND	-1.478	0.928	0.977	2.430	-1.843	0.880	0.927	0.758
HUNGARY	-1.498	0.921	0.969	1.849	-2.160	0.917	0.965	1.626
SLOVAK REP.	-1.386	0.916	0.964	1.578	-1.380	0.950	0.999	90.080
CZECH REP.	-1.316	0.923	0.971	1.985	-2.040	0.855	0.901	0.552
BULGARIA	-4.535	0.843	0.888	0.487	-9.134	0.548	0.582	0.107
ALBANIA	-2.118	0.939	0.988	4.759	-2.315	0.887	0.934	0.845
CROATIA	-1.720	0.861	0.907	0.591	-1.598	0.932	0.981	2.959
LATVIA	-1.706	0.926	0.974	2.231	-1.513	0.953	1.002	n.a.
ESTONIA	-1.788	0.901	0.948	1.092	-1.707	0.930	0.979	2.669
LITHUANIA	-1.075	0.968	1.018	n.a.	-0.161	0.993	1.044	n.a.
SWEDEN	-2.384	0.863	0.909	0.605	-1.446	0.958	1.008	n.a.
NORWAY	-1.682	0.928	0.977	2.430	-2.447	0.827	0.872	0.420
UK	-1.799	0.927	0.975	2.326	-2.666	0.895	0.942	0.971

	Relative to Ukraine				*Relative to US*			
Country	ADF CT	ρ	Adj. ρ	Half-live	ADF CT	ρ	Adj. ρ	Half-live
US / UKRAINE	-1.918	0.880	0.927	0.758	-1.914	0.880	0.927	0.758
RUSSIA	-2.228	0.859	0.905	0.578	-1.468	0.904	0.952	1.164
ROMANIA	-1.350	0.816	0.860	0.384	-3.024	0.648	0.686	0.153
POLAND	-1.699	0.846	0.891	0.502	-1.767	0.804	0.848	0.350
HUNGARY	-1.997	0.831	0.876	0.435	-1.982	0.834	0.879	0.447
SLOVAK REP.	-1.756	0.834	0.879	0.447	-0.452	0.956	1.006	n.a.
CZECH REP.	-2.373	0.776	0.819	0.289	-1.468	0.830	0.875	0.432
BULGARIA	-1.167	0.923	0.971	1.985	-7.622	0.552	0.586	0.108
ALBANIA	-1.927	0.887	0.934	0.845	-2.622	0.810	0.854	0.366
CROATIA	-2.077	0.785	0.828	0.306	-0.036	0.995	1.046	n.a.
LATVIA	-1.558	0.894	0.941	0.953	-3.110	0.812	0.856	0.372
ESTONIA	-1.904	0.853	0.899	0.540	-2.266	0.815	0.859	0.381
LITHUANIA	-2.392	0.832	0.877	0.439	-2.186	0.840	0.885	0.473
SWEDEN	-2.652	0.817	0.861	0.387	-2.756	0.688	0.727	0.181
NORWAY	-3.792	0.727	0.768	0.219	-3.438	0.748	0.790	0.245
UK	-1.855	0.885	0.932	0.818	-2.627	0.859	0.905	0.578

ADF C and ADF CT stand for Augmented Dickey-Fuller test statistics with constant or constant and trend included.

The sample period is 1996.01-2002.09.

10 % critical values are: ADF C 2.589907, ADF CT -3.166190.

Table 5.2 The results of Phillips-Perron tests for a unit root in the real exchange rates (12 lags included)

	Relative to Ukraine				*Relative to US*			
Country	PP C	ρ	Adj. ρ	Half-live	PP C	ρ	Adj. ρ	Half-live
US/UKRAINE	-1.162	0.975	1.025	n.a.	-1.162	0.975	1.025	n.a.
RUSSIA	-2.024	0.931	0.980	2.806	-1.574	0.954	1.004	n.a.
ROMANIA	-1.425	0.928	0.977	2.430	-2.744	0.811	0.855	0.369
POLAND	-1.531	0.945	0.994	9.873	-2.216	0.906	0.954	1.218
HUNGARY	-1.484	0.942	0.991	6.426	-1.409	0.966	1.016	n.a.
SLOVAK REP.	-1.718	0.924	0.972	2.061	-1.500	0.964	1.014	n.a.
CZECH REP.	-1.528	0.940	0.989	5.210	-1.842	0.933	0.982	3.128
BULGARIA	-1.382	0.941	0.990	5.755	-2.793	0.816	0.860	0.384
ALBANIA	-1.080	0.974	1.024	n.a.	-1.688	0.919	0.967	1.730
CROATIA	-2.445	0.872	0.918	0.678	-1.622	0.946	0.995	12.018
LATVIA	-1.405	0.958	1.008	n.a.	-1.243	0.974	1.024	n.a.
ESTONIA	-1.710	0.933	0.982	3.128	-1.524	0.956	1.006	n.a.
LITHUANIA	-0.889	0.983	1.034	n.a.	-0.485	1.002	1.053	n.a.
SWEDEN	-1.944	0.931	0.980	2.806	-1.459	0.969	1.019	n.a.
NORWAY	-1.266	0.963	1.013	n.a.	-1.749	0.931	0.980	2.806
UK	-1.394	0.958	1.008	n.a.	-1.720	0.950	0.999	90.080

	Relative to Ukraine				*Relative to US*			
Country	PP CT	ρ	Adj. ρ	Half-live	PP CT	ρ	Adj. ρ	Half-live
US / UKRAINE	-1.649	0.952	1.001	n.a.	-1.659	0.951	1.000	n.a.
RUSSIA	-1.929	0.931	0.980	2.806	-1.634	0.943	0.992	7.273
ROMANIA	-3.401	0.756	0.798	0.256	-2.941	0.796	0.839	0.330
POLAND	-2.567	0.879	0.926	0.747	-2.208	0.881	0.928	0.770
HUNGARY	-2.411	0.885	0.932	0.818	-1.134	0.971	1.021	n.a.
SLOVAK REP.	-2.646	0.863	0.909	0.605	-0.511	0.986	1.037	n.a.
CZECH REP.	-2.616	0.869	0.915	0.652	-1.354	0.945	0.994	9.873
BULGARIA	-3.092	0.831	0.876	0.435	-3.579	0.744	0.785	0.239
ALBANIA	-1.930	0.929	0.978	2.544	-2.666	0.844	0.889	0.492
CROATIA	-2.845	0.839	0.884	0.469	-1.486	0.905	0.953	1.190
LATVIA	-1.798	0.935	0.984	3.533	-1.917	0.942	0.991	6.426
ESTONIA	-2.221	0.902	0.950	1.115	-1.813	0.928	0.977	2.430
LITHUANIA	-2.054	0.931	0.980	2.806	-1.736	0.957	1.007	n.a.
SWEDEN	-2.129	0.921	0.969	1.849	-1.529	0.939	0.988	4.759
NORWAY	-2.223	0.912	0.960	1.411	-1.838	0.921	0.969	1.849
UK	-1.664	0.938	0.987	4.380	-2.100	0.926	0.974	2.231

PP C and PP CT stand for Phillips-Perron statistics with constant or constant and trend included.

The sample period is 1996.01-2002.09.

10 % critical values are: PP C -2.583, PP CT -3.154

Lithuania is a good illustrative example for my analysis because this country had fixed exchange rate of 4 units of national currency per USD over the period from 01.1996 to 02.2002. It is not surprising that PPP for this country often fails even in the long run[13] (given its nonzero inflation over the sample period).

One possible problem with applying ADF-type unit root tests to Ukrainian data is the apparent structural break in 1998, the year of the Asian financial crisis. As Charemza and Deadman (1997, p. 119) notice, a structural change in the mean of a stationary variable might bias ADF tests towards non-rejection of the unit root null hypothesis. To take this possible structural break explicitly into consideration I perform the Perron 'additive outlier' test in the next section.

5.2. Perron 'additive outlier' test

Charemza and Deadman (1997) argue that Perron 'additive outlier' test allow one to distinguish between a non-stationary process with a "pulse" shock at time t=b and a stationary process with a shift to a permanently higher mean at the same period of time. *A priori* one may expect that over the sample period a major shock occurred in 1998 at the time Asian financial crisis. Indeed, as data inspection shows there is a noticeable change in Ukrainian real exchange rates in September 1998.

The results of Perron 'additive outlier' tests are presented in Table 5.3. The stationarity of Ukrainian real exchange rates (though with a shift to a higher mean) is confirmed by the data for several transition economies when the structural shock of September 1998 is explicitly taken into consideration.

[13] This means that adjusted ρ is in excess of 1 leading to non-feasible negative half-lives.

Table 5.3 Perron 'additive outlier' test

Country	t-statistic on the lagged residual	
US	-1.541	
RUSSIA	-1.884	
ROMANIA	-2.860	
POLAND	-3.402**	
HUNGARY	-3.346**	
SLOVAK REPUBLIC	-3.537*	
CZECH REPUBLIC	-3.282**	
BULGARIA	-3.175**	
ALBANIA	-2.390	
CROATIA	-3.713*	
LATVIA	-2.080	
ESTONIA	-3.181**	
LITHUANIA	-1.554	
SWEDEN	-2.273	
NORWAY	-1.766	
UNITED KINGDOM	-1.541	
Critical values for λ=0.4, n = 75		
Significance level	lower	upper
1%	-4.14	-3.99
2.5%	-3.78	-3.67
5%	-3.47	-3.39
10%	-3.13	-3.07

* Significant at 5 %, ** Significant at 10%. t-statistics are estimated by Eviews 4.1 (refer to Appendix C4 for Eviews output for the second test equation).

Critical values are from Charemza and Deadman (Table 6. Perron 'additive outlier' test, pp. 301-303)

The fact that Ukrainian real exchange rates are stationary with respect to transition but not developed economies might point to similar economic conditions in Eastern European countries and their comparable reaction to financial shocks originating outside.

When a unit root is not rejected in real exchange rates the problem is usually overcome by longer time series or panel data methods. For the reasons outlined above it is impossible to significantly extend sample period for Ukraine. Before

applying the Im-Pesaran-Shin panel unit root test I would like to proceed with testing for possible cointegration in Ukrainian real exchange rates.

5.3. Cointegration and PPP

In the light of our findings it is reasonable to test for a weaker form of PPP. This is possible and consists of testing for a cointegrating relation in the real exchange rates (Verbeek 2000, p. 287):

$$s_t = \alpha + \beta ratio_t + \varepsilon_t,$$

where s_t is the log of real exchange rate, α is a constant and $ratio_t = p_t - p_t^*$ is the difference of the log price levels. In the presence of cointegration the series of OLS residuals ε_t is stationary. As an example, I test for possible cointegration in the real exchange rate of the Ukraine-USA currency pair.

First of all, it is necessary to check the order of series integration. The PP tests of the log real exchange rates st and ratiot show that they are integrated of order one (stationary in first differences)[14].

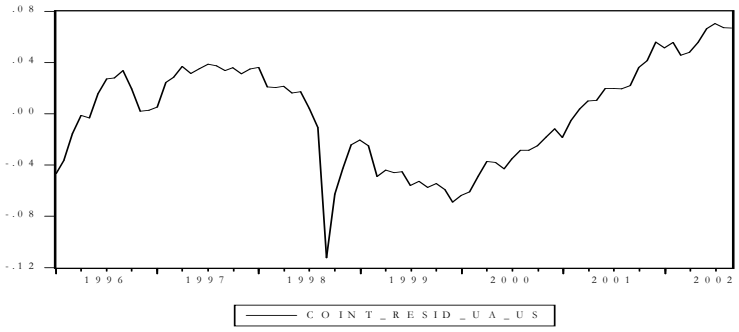

Figure 5.2 Residuals of OLS cointegrating regression for currency pair Ukraine-USA, 1996:01-2002:09

[14] The ADF tests does not reject the unit root null probably due to low power caused by small sample and/or possible structural break in 1998.

The next step is to check the stationarity of the error term of OLS regression which is presented in Figure 5.2. The above figure clearly shows some pattern of nonstationarity, which is confirmed by more formal unit root tests. Indeed, PP (as well as ADF) tests do not reject the null of non-stationarity even with only one lag included.

Again, the major problem probably lies in insufficient length of series, which does not allow one to reject the null of a unit root.

Table 5.4 Unit root tests of residuals of OLS cointegrating regression for Ukraine-USA, 1996:01-2002:09

Null Hypothesis: COINT_RESID_UA_US has a unit root
Exogenous: Constant

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic (1 lag)	-1.402644	0.5770

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: COINT_RESID_UA_US has a unit root
Exogenous: Constant, Linear Trend

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic (1 lag)	-1.428236	0.8451

*MacKinnon (1996) one-sided p-values.

So the results remain inconclusive, which correspond to the claims of Froot and Rogoff (1995, p. 1648):

> "… cointegration approaches have sometimes created as much confusion as clarity on the issue of PPP."

Since this line of research does not seem to be very promising when applied to the extremely short sample period available for Ukraine it is not pursued here any further[15].

[15] However, Appendix C5 presents the results of cointegrating tests for the rest of the sample countries.

5.4. The Im-Pesaran-Shin panel unit root test of PPP

The Im-Pesaran-Shin panel unit root test of the PPP relationship is estimated for the 12 transitional economies, which are expected to have similar speed of adjustment to long-run values of real exchange rates. This is to minimize possible problems with utilizing mixed panels from transitional and developed economies. The results of Im-Pesaran-Shin test with real exchange rates remaining untransformed for the common time effect are presented in Table 5.5.

Table 5.5 The Im-Pesaran-Shin test of PPP with untransformed real exchange rates

T-bar, constant	-1.564	
Critical values of DF regression for constant (N/T=10/70)		
(10%) -1.88	(5%) –1.98	(1%) –2.16

T-bar, constant and trend	-2.307	
Critical values of DF regression for constant and trend (N/T=10/70)		
(10%) –2.49	(5%) –2.58	(1%) -2.75

T-bar critical values for DF regressions are from Im, Pesaran and Shin (2002).

The estimations are made with the help of the Gauss program ipspppas.pgm by Professor Mark (refer to Appendix B for details).

Ukraine is used as numeriare for 12 real exchange rates with transitional economies over the period 1996.01-2002.09.

The IPS panel unit root test does not reject the null hypothesis of a unit root at the conventional 10% significance level. One can also test for unit roots with real exchange rates transformed to account for the common time effect as discussed in Mark (2001, p. 46). The postulated advantage of this method is that it takes common shocks (such as the Asian financial crisis) explicitly into consideration and removes them from the series. The results of IPS test of PPP for the 12 transitional countries are presented in Table 5.6.

Table 5.6 The Im-Pesaran-Shin test of PPP with real exchange rates transformed for common time effect

T-bar, constant		-2.236
Critical values of DF regression for constant (N/T=10/70)		
(10%) -1.88	(5%) –1.98	(1%) –2.16

T-bar, constant and trend		-2.803
Critical values of DF regression for constant and trend (N/T=10/70)		
(10%) –2.49	(5%) –2.58	(1%) -2.75

T-bar critical values for DF regressions are from Im, Pesaran and Shin (2002).

The estimations are made with the help of the Gauss program ipspppas.pgm by Professor Mark (refer to Appendix B for details). The deviations from the cross-sectional mean are used in analysis (Mark 2001).

Ukraine is used as numeriare for 12 real exchange rates with transitional economies over the period 1996.01-2002.09.

The presence of a unit root null in deviations of real exchange rates from their cross-sectional means can be rejected even at a 1% significance level. In line with the results of the univariate tests, there is more evidence in support of PPP when common shocks in Ukrainian real exchange rates are controlled for in this fashion. The results obtained might point to similar time pattern of behaviour for exchange rates in the considered transitional economies as those exhibited by Ukrainian real exchange rates. Thus, with a panel of the 12 transitional economies the results of PPP testing are consistent with those of the univariate tests.

Chapter 6

CONCLUSIONS

The evidence on the validity of PPP in Ukraine versus a number of developed and transition countries is mixed, suggesting that the methodology used is crucial for the results. On the one hand, the data do not support stationarity of Ukrainian real exchange rates or cointegrating relations in Ukrainian nominal exchange rates and price level changes. This short-run violation of PPP is neither surprising nor disappointing given other empirical findings reported in the literature and the well-known problems surrounding unit root testing.

On the other hand, estimated half-lives to convergence show relatively quick adjustment to long-run values of Ukrainian real exchange rates. Including a linear trend into specification in general shortens half-lives from 1-2 years to less than one year, pointing to a possible trend in Ukrainian real exchange rates.

Another important finding is that of comparable half-lives to convergence when Ukraine or United States is used as numeraire over the sample period. Macroeconomic stabilization policies in Ukraine since 1996 onwards, combined with relatively low inflation of 14.6% annually, have led to similar long-run adjustment of Ukrainian compared with US real exchange rates.

More evidence in support of PPP in Ukraine is found when the structural change caused by the Asian financial crisis of 1998 is explicitly taken into consideration. The non-stationarity is rejected in favour of stationary Ukrainian real exchange rates with a permanently higher mean.

Finally, the Im-Pesaran-Shin panel unit root test gives mixed results as well. The unit root null cannot be rejected for a panel of Ukrainian real exchange rates at conventional significance levels. However, the Im-Pesaran-Shin test rejects the unit root null when observations are transformed for the common time effect, pointing to possibly similar behaviour in Ukrainian real exchange rates for the considered transitional economies.

Thus, there are no theoretical grounds and, in general, no empirical evidence to suggest that PPP fails completely in Ukraine as compared with both transition and developed countries. The analysis has shown the absence of a prolonged real appreciation or depreciation in Ukrainian real exchange rates from January 1996 onwards. Although the real exchange rates are not stationary over the sample period there exists some adjustment (though not the same for all currencies and over all sample periods) to the long-run level of the real exchange rates of Ukrainian currency as a result of domestic and foreign price level changes.

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APPENDIX A

Detailed data description and data sources

1. The wholesale price index (WPI) for Ukraine for December 2000 - December 2002 are downloaded from NBU official website (www.bank.gov.ua, accessed on January 22, 2003). Testing for the data consistency with IMF source gives identical results for the overlapping sample.
2. Lithuania has a fixed exchange rate of 4 units of national currency per USD for 01.1995 to 02.2002.
3. Exchange rate for Russia was calculated as cross-rate of exchange rates of UAH/USD and UAH/RUB because there is no reliable data available from the IMF for the whole sample period.
4. The following proxies (if different from the wholesale or producer price indices) are used as proxies for inflation:
   a. For Sweden - Prices: domestic supply (IFS line 63)
   b. For Spain - Industrial prices (IFS line 63)
   c. For Albania – CPI (IFS line 64)
   d. For France – CPI (IFS line 64)
   e. For Switzerland - Total supply index (IFS line 63S)
   f. For Denmark - Wholesale prices, home goods, (IFS line 63A, no data for 07-09.2002)
   g. For UK – WPI, Industrial output (IFS line 63)
   h. For Bulgaria - CPI (IFS line 64)
5. All values are rounded to three digital points

APPENDIX B

Description of Gauss programs and procedures

Gauss programs and procedures used for estimation are downloaded from Professor N. Mark website which accompanies:

> Mark, Nelson C. International Macroeconomics and Finance: Theory and Econometric Methods. Oxford: *Blackwell Publishers*.2001. (http://www.econ.ohio-state.edu/Mark/book/book.htm)

The Gauss procedures used for estimation are downloaded from the page http://www.econ.ohio-state.edu/Mark/book/gaussproc/gaussproc.htm (accessed on April, 10, 2003)

1. ols.set - The procedure to do OLS
2. adf.set – The procedure to calculate studentized coefficient of the ADF test
3. uroot.set – The procedure to do ADF and Phillips-Perron tests for a unit root

The Gauss programs used for estimation are downloaded from the page http://www.econ.ohiostate.edu/Mark/book/rexra/rexrapage.htm (accessed on April, 10, 2003)

1. ppp1.pgm - The program to do ADF in real exchange rates
2. adfpval1.pgm – The program to calculate p-values of the ADF test
3. ipspppas.pgm –The program to perform Im-Pesaran-Shin test

APPENDIX C1

The p-values of ADF tests

Country	ADF C	p-values	ADF CT	p-values
US	-1,794	0,379	-1,918	0,640
RUSSIA	-2,687	0,087	-2,228	0,484
ROMANIA	-2,420	0,144	-1,350	0,869
POLAND	-1,478	0,537	-1,699	0,749
HUNGARY	-1,498	0,527	-1,997	0,597
SLOVAK REPUBLIC	-1,386	0,585	-1,756	0,720
CZECH REPUBLIC	-1,316	0,621	-2,373	0,412
BULGARIA	-4,535	0,000	-1,167	0,903
ALBANIA	-2,118	0,236	-1,927	0,634
CROATIA	-1,720	0,414	-2,077	0,560
LATVIA	-1,706	0,419	-1,558	0,811
ESTONIA	-1,788	0,381	-1,904	0,647
LITHUANIA	-1,075	0,730	-2,392	0,398
SWEDEN	-2,384	0,149	-2,652	0,275
NORWAY	-1,682	0,433	-3,792	0,022
UNITED KINGDOM	-1,799	0,378	-1,855	0,672

The p-values are estimated by the Gauss program adfpval1.pgm (The author is Professor Mark, see Appendix B for details) over the period 1996.01-2002.09 with 12 lags included.

ADF C and ADF CT stand for Augmented Dickey-Fuller test with constant or constant and trend included.

APPENDIX C2

The results of ADF and PP tests over the extended period (1994.06-2002.09)

Country	ADF C	p-value	ρ	Half-life	ADF CT	p-value	ρ	Half-life
US	-1.858	0.349	0.953	7.975	-1.863	0.672	0.935	2.212
ROMANIA	-1.376	0.606	0.934	2.126	-2.966	0.133	0.771	0.267
POLAND	-1.831	0.358	0.928	1.722	-2.236	0.455	0.897	0.860
HUNGARY	-1.929	0.315	0.919	1.337	-2.459	0.340	0.881	0.680
SLOVAK REPUBLIC	-2.158	0.203	0.898	0.875	-2.741	0.210	0.863	0.548
CZECH REPUBLIC	-1.855	0.351	0.914	1.189	-2.520	0.313	0.872	0.607
BULGARIA	-1.398	0.596	0.936	2.306	-2.268	0.440	0.851	0.485
ALBANIA	-1.619	0.467	0.956	13.978	-2.317	0.416	0.906	1.008
CROATIA	-2.434	0.126	0.868	0.580	-2.524	0.307	0.863	0.548
LATVIA	-1.684	0.436	0.941	2.920	-1.945	0.627	0.915	1.216
ESTONIA	-1.885	0.335	0.910	1.091	-2.267	0.440	0.880	0.671
LITHUANIA	-1.012	0.761	0.976	-3.531	-1.896	0.656	0.917	1.274
SWEDEN	-2.368	0.138	0.902	0.937	-2.371	0.385	0.901	0.920
NORWAY	-1.734	0.407	0.936	2.306	-2.486	0.328	0.890	0.771
UK	-2.027	0.265	0.933	2.046	-2.362	0.390	0.901	0.920

Country	PP C	ρ	Adjust. ρ	Half-life	PP CT	ρ	Adjust. ρ	Half-life
US	-2.558	0.876	0.913	0.638	-2.622	0.865	0.902	0.560
ROMANIA	**-2.834**	0.854	0.891	0.499	-3.083	0.822	0.858	0.376
POLAND	**-3.313**	0.818	0.854	0.365	**-3.300**	0.817	0.853	0.362
HUNGARY	**-3.151**	0.822	0.858	0.376	-3.128	0.822	0.858	0.376
SLOVAK REPUBLIC	**-3.273**	0.822	0.858	0.376	**-3.326**	0.820	0.856	0.371
CZECH REPUBLIC	**-3.121**	0.830	0.866	0.401	-3.101	0.828	0.864	0.395
BULGARIA	-2.583	0.880	0.918	0.671	-3.016	0.840	0.876	0.437
ALBANIA	-2.011	0.916	0.955	1.244	-2.347	0.888	0.926	0.749
CROATIA	**-2.824**	0.841	0.877	0.441	-3.101	0.825	0.861	0.385
LATVIA	**-3.418**	0.815	0.851	0.357	**-3.455**	0.806	0.841	0.334
ESTONIA	**-4.225**	0.760	0.794	0.250	**-4.231**	0.757	0.791	0.246
LITHUANIA	-2.412	0.898	0.936	0.875	**-3.323**	0.821	0.857	0.373
SWEDEN	**-3.152**	0.825	0.861	0.385	**-3.378**	0.814	0.849	0.354
NORWAY	-2.443	0.887	0.925	0.738	-2.561	0.875	0.912	0.630
UK	**-2.993**	0.845	0.881	0.458	**-3.022**	0.837	0.873	0.426
Critical value at 10 %			PP C	-2.583			PP CT	-3.154

Adjusted for bias half-lives are measured in years. The significance of test statistics at the 10 % level is indicated in bold face.

The results of unit root tests and ρ are computed by the Gauss program ppp1.pgm (The author – Professor Mark, see Appendix B for details) with 12 lags included. The p-values are calculated by the Gauss program adfpval1.pgm (The author is Professor Mark, see Appendix B for details).

ADF C and ADF CT stand for Augmented Dickey-Fuller test with constant or constant and trend included. PP C and PP CT stand for Phillips-Perron test with constant or constant and trend included.

APPENDIX C3

Results of unit root tests in real exchange rates by Mark (2001).

Table 7.2 Augmented Dickey-Fuller tests for a unit root in post-1973 real exchange rates

	Relative to US			*Relative to Germany*		
Country	τ_c	*(p- value)*	*Half-life*	τ_c	*(p-value)*	*Half-life*
Australia	-1.895	(0.329)	4.582	-2.444	(0.124)	2.095
Austria	-2.434	(0.126)	3.208	**-3.809**	(0.004)	5.516
Belgium	-2.369	(0.138)	4.223	**-2.580**	(0.093)	2.914
Canada	-1.342	(0.621)	—	-2.423	(0.127)	2.914
Denmark	-2.319	(0.155)	3.733	**-3.212**	(0.017)	1.759
Finland	**-2.919**	(0.039)	2.421	**-2.589**	(0.089)	3.208
France	-2.526	(0.105)	2.761	**-4.540**	(0.001)	0.695
Germany	-2.470	(0.118)	3.025	—	—	—
Greece	-2.276	(0.169)	4.336	-2.360	(0.140)	1.278
Italy	-2.511	(0.107)	2.580	-1.855	(0.351)	5.709
Japan	-2.057	(0.252)	9.251	-1.930	(0.314)	11.919
Korea	-1.235	(0.677)	3.274	-2.125	(0.215)	1.165
Netherlands	**-2.576**	(0.094)	2.623	**-2.676**	(0.075)	2.969
Norway	-2.184	(0.193)	2.668	**-2.573**	(0.095)	2.539
Spain	-2.358	(0.140)	5.006	-2.488	(0.113)	2.861
Sweden	-2.042	(0.257)	5.516	-2.534	(0.103)	1.719
Switzerland	**-2.670**	(0.076)	2.215	**-3.389**	(0.011)	1.759
UK	-2.484	(0.113)	2.313	-2.272	(0.169)	3.274

Half-lives are adjusted for bias and are measured in years. The significance at the 10 percent level is indicated in bold face.

Source: Mark, Nelson C. International Macroeconomics and Finance: Theory and Econometric Methods. Oxford: *Blackwell Publishers*.2001, p. 172.

APPENDIX C4

Eviews output for Perron 'additive outlier' test (2nd equation)

Country	Coefficient	Std. Error	t-Statistic	Prob.
US	-0.059	0.038	-1.541	0.128
RUSSIA	-0.069	0.036	-1.884	0.063
ROMANIA	-0.204	0.071	-2.860	0.005
POLAND	-0.179	0.053	-3.402	0.001
HUNGARY	-0.188	0.056	-3.346	0.001
SLOVAK REPUBLIC	-0.177	0.050	-3.537	0.001
CZECH REPUBLIC	-0.168	0.051	-3.282	0.002
BULGARIA	-0.228	0.072	-3.175	0.002
ALBANIA	-0.152	0.064	-2.390	0.019
CROATIA	-0.209	0.056	-3.713	0.000
LATVIA	-0.088	0.042	-2.080	0.041
ESTONIA	-0.159	0.050	-3.181	0.002
LITHUANIA	-0.053	0.034	-1.554	0.124
SWEDEN	-0.082	0.036	-2.273	0.026
SWITZERLAND	-0.144	0.041	-3.543	0.001
NORWAY	-0.072	0.041	-1.766	0.081
UNITED KINGDOM	-0.059	0.038	-1.541	0.128
Critical values for λ=0.4, n = 75				
Significance level		lower	upper	
	1%	-4.14	-3.99	
	2.5%	-3.78	-3.67	
	5%	-3.47	-3.39	
	10%	-3.13	-3.07	

APPENDIX C5

Phillips-Perron tests for cointegration

	PP C		PP CT	
Country	Adj. t-Stat	Prob.*	Adj. t-Stat	Prob.*
UNITED STATES	-1.7679	0.3937	-1.7724	0.7089
RUSSIA	-2.0132	0.2808	-1.9596	0.6140
ROMANIA	-2.0900	0.2492	-2.0338	0.5739
POLAND	-2.6597	**0.0856**	-2.6441	0.2625
HUNGARY	-2.2910	0.1774	-2.2723	0.4437
SLOVAK REPUBLIC	-3.0076	**0.0384**	-2.9486	0.1534
CZECH REPUBLIC	-2.5632	0.1049	-2.5253	0.3155
BULGARIA	-1.5820	0.4871	-2.4833	0.3355
ALBANIA	-1.7427	0.4061	-1.7184	0.7340
CROATIA	-3.1151	**0.0294**	-3.0731	0.1199
LATVIA	-1.8541	0.3522	-1.8550	0.6683
ESTONIA	-2.2552	0.1890	-2.2562	0.4524
LITHUANIA	-2.2553	0.1890	-2.2417	0.4602
SWEDEN	-2.2717	0.1836	-2.2452	0.4583
NORWAY	-1.9797	0.2952	-2.2256	0.4689
UNITED KINGDOM	-1.5385	0.5092	-1.4697	0.8319

*MacKinnon (1996) one-sided p-values. Table reports results of unit root tests of residuals of OLS cointegrating regression for Ukraine versus a number of selected countries. All tests are performed with 12 lags included.

PP C and PP CT stand for Phillips-Perron test with constant or constant and trend included.

The values significant at 10% are given in the bold space.