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Random Walks in the Real Exchange Rates of 20 OECD Countries: Recent Evidence from the Panel Integration and Cointegration Tests

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Abstract

We study the real exchange rates of 20 OECD countries over the 1970-2020 period. The panel unit root tests developed by Im, Pesaran, and Shin (2003) and Pesaran (2007) reveal no evidence of unit roots. However, allowing for the presence of cross-sectional dependence, we find significant evidence of unit roots. We also attempt to explain the deviation of the real exchange rates from their PPP levels by testing for the presence of cointegration between these variables and some of their potential determinants, such as differences in national productivities and the price of oil, again drawing on more powerful panel cointegration tests of Larsson, Lyhagen and Löthgren (2001). Our findings strongly support the presence of cointegration for all the countries in the sample, thus providing additional evidence for the existence of higher real exchange rates in the countries with higher productivities. Hence, our findings also necessitate the adoption of more coordinated economic policies within the OECD to avoid the balance of international crises that periodically afflict the member countries.

Keywords: exchange rate, cointegration, purchasing power parity.

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I. Introduction

Testing for unit roots in macroeconomic time series is nowadays commonplace, as the presence of unit roots can have important implications for both theoretical and empirical dynamic econometrics. The existence of unit roots demonstrates the short run deviations of the underlying variables from their long run equilibrium values are persistent and irreversible. This finding contradicts many of the existing theories of economic and financial behavior, where such deviations are assumed to be short-lived and self-correcting. Given the unfamiliar implications of unit root processes, there have been attempts to either justify them by new theoretical models (e.g., real business cycle theory to explain the presence of unit roots in real outputs introduced by Kydl and Prescott, 1982; the efficient market hypothesis to justify the stock prices random walk by Fama, 1991). A number of unit root tests have been developed which draw on the Bayesian (Schotman and van Dijk, 1991), nonlinear autoregression (Balke and Fomby, 1997; Perron, 1989; Zivot and Andrews, 1992; Enders and Granger, 1998; Kapetanios, Shin, and Snell, 2002), and panel data approaches (Levin and Lin, 1993; Maddala and Wu, 1999; Im, Pesaran, and Shin, 2003; Pesaran, 2007).

Among the above unit root tests, the panel data approach has received considerable attention in recent years (see Hsiao, 2007, for an excellent survey). The rapid spread of panel unit root tests could be attributed to the fact that the standard augmented Dickey-Fuller (1979; henceforth ADF)unit root test which relies on individual time series demonstrates limited power in differentiating between nonstationary and stationary but persistent autoregressive processes. In their work Levin and Lin (1993) and Quah (1994) use panel data which enhances the power of the ADF test, particularly when applied to small samples. Currently, there is a wide array of panel data available which includes both numerous members and long sample durations. Recently, the panel unit root tests have been extended to allow for both heterogeneity and cross section dependence of the panel members, thus offering more realistic alternative hypotheses (Maddala and Wu, 1999; Im, Pesaran and Shin, 2003; Moon and Perron, 2004; Pesaran, 2007).

This paper applies the panel unit root tests to analyze the behavior of the real exchange rates in 20 OECD countries over the 1970-2020 period. Given the importance of the real exchange rate as a key macroeconomic variable, there already exists a voluminous empirical literature on its time series behavior (see Rogoff, 1996, and Sarno and Taylor, 2002, and Taylor, 2006, for excellent surveys of the literature). Previous empirical research examines whether the real exchange rates are characterized by the presence of unit roots during the recent float, a condition unfavorable to the long run mean reversion of the real exchange rates and; therefore, to the empirical validity of the long run purchasing power parity (PPP). Roll (1979), Adler and Lehmann (1983), Taylor (1988), Mark (1990), and Fraser et al. (1991),

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among others, have found evidence of unit roots in the real exchange rate for many industrial and developing countries. Since these findings are inconsistent with the long run PPP, other researchers using a variety of other approaches (e.g., including fractional integration, multivariate cointegration, and longer sample periods), have uncovered evidence more favorable to the stationarity of the real exchange rates (Taylor and McMahon, 1988; Kugler and Lenz, 1993; Frankel and Rose, 1996; Lothian and Taylor, 1996; MacDonald, 1996; Baum et al., 1999; Flores, et al., 1999; Cheung and Lai, 2000; Taylor, 2002). At the same time, using panel data unit root tests, Frankel and Rose (1996) and Oh (1996), among others, have also uncovered support for the mean reversion of the exchange rates. The problem with these latter studies, however, is their reliance on the cross-sectional independence of the panel members, obviously an unrealistic assumption, given the numerous economic and financial shocks affecting these members over the period under review. Indeed, our findings to be reported later in the paper demonstrate the presence of cross-sectional dependence among our panel members, thus throwing doubt on the robustness of these earlier studies.

This paper contributes to the evidence on the empirical validity of the long run PPP by testing for the nonstationarity of the real exchange rate in the context of a panel of 20 OECD countries from 1970 to 2020. Our study includes a larger number of major industrial countries and for a longer time period than many earlier studies. Unlike the earlier research, we specifically test and find cross sectional dependence among the panel data, a finding that requires the use of the more powerful Pesaran (2007) panel unit root test.

Since the results to be later presented in the paper demonstrate the presence of unit roots in the real exchange rates of our sample OECD countries, a related issue arises as to whether there is a long run relationship between the real exchange rates and some of their potential determinants, such as the national differences in the levels of economic productivity and the price of oil. This paper attempts to shed additional light on this issue by testing for the presence of cointegration between the real exchange rates and their determinants, using the standard Johansen (1991) test and the more robust Larsson, Lyhagen and Löthgren (2001) panel cointegration test. The rest of the paper is organized as follows: section II focuses on methodology. Section III focuses on empirical findings. Section IV lists limitations and recommendations for Future Research. Section V concludes.

II. Methodology

The purpose of this research is to test the null hypothesis of unit roots in the real exchange rates on the example of OECD countries, using the recently developed panel cointegration tests of Larsson, Lyhagen and Löthgren (2001) and panel unit root tests.

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Authors state that the power of often employed the Augmented Dickey-Fuller (ADF) test and Johansen (1988) test could be distorted when data sample is too small. To increase the power of the ADF test, some studies use monthly or quarterly data; however, it possibly could present regime shifts and other structural breaks over longer time series. Use of panel data could improve the power of the standard root tests (e.g., Levin and Lin, 1992; Maddala, 1998, for a contrary view). For example, Levin and Lin (LL, henceforth) start from the standard ADF test for each of the N members of a panel over T periods, as follows:

$$\Delta y_{i,t} = \alpha_i + \rho\, y_{i,t-1} + \sum_{j=1}^{j=\rho_i} \beta_{i,j} \Delta y_{i,t-j} + \varepsilon_{i,t} \quad (1)$$

where i = 1…., N, t = 1…., T, and $\varepsilon_{i,t} \approx idd\ (0, \sigma_i^2)$. In this test, the null and alternative hypotheses are, respectively, defined as:

$$H_0 : \rho = 0, \quad (2)$$

$$H_1 : \rho < 0. \quad (3)$$

Using pooled cross-section time series data to test the unit root hypothesis, LL show that their pooled estimate of ρ follows a standard normal distribution. One limitation of the LL test is its dependence on a uniform speed of adjustment across all panel members - an improbable assumption for practical applications (e.g., Maddala and Wu, 1999). Im, Pesaran and Shin (1997; 2003) research addresses this limitation: they assume that panel members have different speeds of adjustment. Im, Pesaran and Shin (IPS, henceforth) test is based on the following ADF regressions for all panel members:

$$\Delta y_{i,t} = \alpha_i + \rho_i y_{i,t-1} + \sum_{j=1}^{j=\rho_i} \beta_{i,j} \Delta y_{i,t-j} + \varepsilon_{i,t}\ , \quad (4)$$

where the null and alternative hypotheses are now defined as:

$$H_0 : \rho_i = 0, \quad \text{for all i =1……,N} \quad (5)$$

$$H_1 : \rho_i < 0. \quad \text{for some i =1……, N} \quad (6)$$

IPS propose their $\bar{t}$ test statistic as the average of the corresponding ADF *t*-statistics (t_i) after the separate ADF regressions for all panel members are estimated:

$$\bar{t} = \frac{1}{N}\sum_{i=1}^{N} t_i \quad (7)$$

Under the assumption of cross-sectional independence, and applying the Lindberg-Levy central limit theorem, IPS demonstrate that their $\bar{t}$ statistic exhibits an asymptotically normal distribution. Next, IPS use Monte Carlo simulations to compute the mean (μ) and variance (var) of the ADF t-statistic for different values of N, T and ADF lag (p_i) in order to standardize the $\bar{t}$ distribution. Consequently, the IPS test is often used in the context of balanced panels (same T) with the same ADF lag length to confirm identical distribution for the ADF t-statistic across all panel members. Under these conditions, the standardized $\bar{t}$ statistic, denoted by $\bar{z}$, can be written as:

$$\bar{z} = \frac{\sqrt{N}\,(\bar{t} - \mu)}{\sqrt{var}} \tag{8}$$

A main deficiency of the panel unit root tests is their assumption of cross-sectional independence across the panel members. O'Connell (1998) finds that the unwarranted adoption of the cross-sectional independence could seriously misrepresent the size of the standard panel root tests. Bai and Ng, 2003; Choi, 2001; Phillips and Sul, 2003; Moon and Perron (2004); Pesaran (2007), for example, have attempted to address this issue in the context of various factor and error component models. Pesaran (2007), for example, suggests a modified version of the IPS test, in which the standard ADF test is further augmented by the lagged values of the level and first differences of the cross-section average of the individual series:

$$\Delta y_{i,t} = \alpha_i + \rho_i y_{i,t-1} + c_i \bar{y}_{i,t-1} + \sum_{j=1}^{j=\rho_i} \beta_{i,j} \Delta y_{i,t-j} + \sum_{j=0}^{j=\rho_i} d_{i,j} \Delta \bar{y}_{i,t-j} + v_{i,t}, \tag{9}$$

where $\bar{y}_t = \frac{1}{N}\sum_{i=1}^{N} y_{i\,t}$. Following a procedure like IPS, the Pesaran test is now based on the average of the CADF (cross sectionally augmented ADF) t-statistics for the significance of ρ_i in equation 9:

$$\overline{tt} = \frac{1}{N}\sum_{i=1}^{N} t_i \tag{10}$$

Since the panel members are cross sectionally dependent, the $\overline{tt}$ statistic does not have an asymptotic normal distribution. Pesaran, after applying simulations, offers the critical values of the standardized version ($\overline{zz}$, hereafter) of this statistic for various sample and panel sizes. Before the application of the above panel root tests, it is necessary to ascertain whether the underlying panels are characterized by the presence of cross-sectional dependence. We use the diagnostic techniques developed by Breusch and Pagan (1980) and Pesaran (2004).The Breusch-Pagan Lagrange Multiplier (LM) test is based on the following test statistic:

$$LM = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N} \rho^{2}_{\ ij} \tag{11}$$

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where ρ_{ij} is the Pearson correlation coefficient between the estimated residuals from the ADF regressions of the panel members i and j. Under the null of no cross-sectional dependence, the LM statistic has a chi-squared distribution with N(N-1)/2 degrees of freedom. In a similar way, the Pesaran cross sectional dependence (CD) test is based on the following test statistic:

$$\text{CD} = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\rho_{ij}\right) \tag{12}$$

where ρ_{ij} is defined as before. Under the null of no cross-sectional dependence, the Pesaran CD statistic has asymptotically a standard normal distribution.

Our discussion so far has centered on the methodological issues surrounding the use of more robust panel unit root tests. Of related interest is the use of the equally more robust panel cointegration tests in establishing the presence of long run relationships among variables characterized by unit roots. Johansen (1991) is the most popular non-panel cointegration test in a multivariable context. The Johansen test follows the assumption that the data with unit roots can be described by a VAR in levels of order q as follows:

$$y_t = \prod{}_1 y_{t-1} + \prod{}_2 y_{t-2} + \cdots + \prod{}_q y_{t-q} + \mu_t \tag{13}$$

where y_t is a vector of *n* difference-stationary variables and μ_t is a vector of Gaussian white noise disturbances. The above VAR can be restated in the first differences of the variables as follows:

$$\Delta y_t = \prod y_{t-1} + \Gamma_1 \Delta y_{t-1} + \Gamma_2 \Delta y_{t-2} + \cdots + \Gamma_{q-1} \Delta y_{t-q+1} + \mu_t \tag{14}$$

Elements of y_t are cointegrated if they have linear combinations that are stationary. Johansen (1991) has shown that if there are *r* cointegrating vectors, the rank of Π equals $r < n$, such that Π can be factored as the product of two *n* x *r* matrices $(\Pi = -\beta\alpha')$, where α represents the matrix of *r* cointegrating vectors and β represents the matrix of adjustment coefficients. Under the cointegration assumption, equation 14 can be expressed in the following error correction model (ECM) form:

$$\Delta y_t = -\beta Z_{t-1} + \Gamma_1 \Delta y_{t-1} + \Gamma_2 \Delta y_{t-2} + \cdots + \Gamma_{q-1} \Delta y_{t-q+1} + \mu_t \tag{15}$$

where $Z_t \equiv \alpha' y_t$ represents the error correction terms. Johansen then introduces a likelihood ratio-based trace statistic to test for the number of cointegrating vectors r.

Larsson, Lyhagen and Löthgren (2001) extend the Johansen test by offering a standardized average trace statistic ($\overline{zzz}$) for the panel members, which, under the null hypothesis of r cointegrating vectors, follows an asymptotic normal distribution. More specifically, we have:

$$\overline{zzz} = \frac{\sqrt{N}\,(\overline{Trace} - \mu)}{\sqrt{var}} \qquad (16)$$

where $\overline{\text{Trace}}$ = average trace for all panel members, and μ and var are the mean and variance of $\overline{\text{Trace}}$ as tabulated by Larsson, et al. (2001).

III. Empirical Results

The annual data on the OECD real exchange rates between 1970 and 2020 are defined bilaterally for each country against the US dollar and are expressed in natural logarithms. A typical real exchange rate is defined as the ratio of the domestic to the US prices, where all prices are measured in terms of the domestic currency. This means that any appreciation of the real exchange rate of a country against the US dollar will indicate a weakening of the international competitive position of that country relative to the US. First, we conduct the augmented Dickey-Fuller(ADF) unit root tests of the real exchange rates against the alternative hypotheses that they are all stationary around a constant (a visual inspection of the real exchange rates showed no clear trend for the countries in the sample, no time trends were included in the Dickey-Fuller tests). The implementation of the Dickey-Fuller test demands the whitening of the error terms associated with the auxiliary equations of these tests by adding an appropriate number of lags of the first differences of the underlying variables to these equations. To achieve the appropriate lag length for our sample countries, the Akaike information criterion (Akaike, 1973) is used for a VAR in all the real exchange rates. Starting from a maximum lag of three years, the Akaike procedure selected a lag of only one year. The ADF unit root test results are presented in Table 1. We are unable to reject the null of a unit root for six of our twenty sample countries (Canada, Ireland, Italy, Portugal, Turkey, and UK).

Table 1. ADF Unit Root Test Results

Country	**t test**	**Country**	**t test**
Australia	-3.04*	South Korea	-3.16*
Belgium	-3.73*	Luxemburg	-3.98*
Canada	-2.57	Netherlands	-3.94*
Denmark	-3.58*	New Zealand	-3.10*
Finland	-3.97*	Norway	-3.30*
France	-3.45*	Portugal	-1.96
Germany	-3.47*	Spain	-3.36*
Ireland	-2.72	Sweden	-3.58*
Italy	-2.63	Turkey	-2.14
Japan	-3.09*	United Kingdom	-2.77

* Indicates significant at the 5 percent level.

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These findings provide support for the presence of mean-reversion in the real exchange rates, and the empirical validity of the long run PPP, for most of our sample countries. Having largely rejected the random walk behavior of the real exchange rates within the ADF framework, we proceed to examine the time series properties of these rates within a panel unit roots model. The use of the OECD panel should provide additional power to our ADF unit root tests. We apply the IPS test, ignoring momentarily the issue of the cross-sectional dependence of the panel members. Next, we individually estimate the standard ADF regression for each panel member, and calculate the corresponding IPS $\bar{z}$ statistic as defined by 5 above. As before, the $\bar{z}$ statistic has an asymptotic normal distribution. Based on the value of $\bar{z}$ for our panel, -9.37, which is highly significant at the 5 percent level, the IPS test also strongly rejects the null hypothesis of unit roots for our panel. We cannot reject mean reversion in the real exchange rate in the context of our sample countries. However, the IPS test can result in spurious findings in the presence of cross-sectional dependence across panel members. Thus, we test for cross sectional dependence among our sample countries.

The cross-sectional dependence of panels is tested based on the LM and CD diagnostic tests. The implementation of these tests calls that we first estimate the pairwise correlations for all the residuals from the ADF regressions run separately for individual panel members. Using these estimated residuals, we then calculate the corresponding correlations and their associated diagnostic test statistics. The Breusch-Pagan LM statistic, which has a chi-squared distribution with 190 degrees of freedom for our sample, has a value of 8,435.91 and is highly significant at the 5 percent level. The Pesaran CD test statistic, which has a standard normal distribution, has a value of118.45, highly significant at the 5 percent level. Both our diagnostic tests strongly reject the null hypothesis of no cross-sectional dependence for our sample countries.

These findings render the application of the IPS test in its original form untenable. Consequently, the correct methodology is provided by the Pesaran-modified IPS test.

To apply Pesaran test, we first separately estimate the cross sectionally augmented ADF regression 9 (CADF) for all sample countries. The results are reported in Table 2. We determine the cross sectionally modified IPS statistic ($\overline{tt}$) as the average of the standard t-statistics from the estimated CADFs. The standardized value of this statistic ($\overline{zz}$) can then be compared to the critical values tabulated by Pesaran to assess its significance. The estimated $\overline{zz}$ statistic has a value of 2.25, which is larger than the 5 percent critical value of -2.11 provided by Pesaran. Therefore, at the 5 percent level of significance, we cannot reject the null hypothesis of unit roots in the exchange rate for our sample countries. These results are at odds with those found earlier for our standard IPS test, where the presence of cross-sectional dependence across our panel members was ignored. Based on these more robust test results, like

Pesaran (2007) in the context of smaller sample and panel sizes, we raise questions about the empirical validity of the long run PPP.

Table 2. CADF Unit Root Test Results

Country	t test	Country	t test
Australia	-2.50	South Korea	-2.95
Belgium	-1.21	Luxemburg	-1.49
Canada	-2.49	Netherlands	-1.66
Denmark	0.05	New Zealand	-1.35
Finland	-1.43	Norway	-2.74
France	-1.43	Portugal	0.32
Germany	-1.18	Spain	0.13
Ireland	0.04	Sweden	-1.86
Italy	0.16	Turkey	-1.27
Japan	-1.88	United Kingdom	-1.86

Given the presence of unit roots in our real exchange rates, we proceed to test for the existence of cointegration between these variables and some of their potential determinants. We are interested in whether the real exchange rates of our sample countries can in part be explained by the existing technological gaps between these countries and the US, as measured by the sizes of their real GDPs per capita. Since technological progress can reduce the levels of production costs and prices of the tradable goods, we expect that any increase in the size of the technological gap of any sample country relative to the US to initially result in the effective depreciation of the real exchange rate of that country against the US dollar.

According to the well-known Balassa-Samuelson (1964) effect, the subsequent competitive increases in the wages and prices of the non-tradable sectors eventually push the aggregate price levels in the more advanced countries higher, resulting in the eventual appreciation of the real exchange rates for those countries. This means that the prices in more advanced economies have an upward productivity bias, a fact that can render the currencies of these countries to become overvalued. In this light, and in the context of our cointegration equations, we expect that the long run real exchange rate of any sample country to depend positively on the size of the relative productivity gap for that country. Given that the higher oil prices can adversely affect the levels of costs and prices in oil importing countries, we expect that any increase in oil prices to result in an increase in the real exchange rates. In other words, we anticipate that the real exchange rate for any sample country to depend positively on the real price of oil.

To test the above expectations, we use the individual and the panel cointegration tests. Table 3 presents the country-by-country and the panel cointegration test results under three different hypotheses regarding the number of cointegrating vectors (r = 0, r = 1, and r = 2). Starting from the Johansen trace test results for the individual countries, the table shows the presence of one cointegrating vector for 13 countries

(Australia, Belgium, Denmark, Finland, France, Ireland, Japan, South Korea, Netherland, New Zealand, Spain, and Turkey), two cointegrating vectors for one country (Norway), and no cointegrating vectors for six countries(Canada, Italy, Luxembourg, Portugal, Sweden and UK).The use of the more robust panel cointegration test indicates the presence of only one cointegrating vector for all the sample countries. As Table 3 shows, the average trace values are respectively 41.47, 12.08, and 3.13 for r = 0, 1, and 2. Adjusting these average trace values for their small sample biases, as suggested by Reinsel and Ahm (1992), and standardizing these corrected average trace values by their simulated means and variances given by Breitung (2005), we obtain the $\overline{zzz}$ values of, respectively, 13.71, 1.42 and -0.19, where only the first value exceeds 1.645, the 5% critical value for a normal distribution. We find only one cointegrating vector for each country in the sample.

Table 3. Standard and Panel Cointegration Test Results

	r = 0	**r = 1**	**r = 2**		**r = 0**	**r = 1**	**r = 2**
Country	**Trace**	**Trace**	**Trace**	**Country**	**Trace**	**Trace**	**Trace**
Australia	35.88*	16.11	4.47	S Korea	84.46*	9.98	2.63
Belgium	85.02*	14.00	5.58	Luxemburg	23.04	10.70	1.15
Canada	19.98	11.44	3.91	Netherlands	38.69*	12.07	0.81
Denmark	36.70*	11.25	2.16	N Zealand	50.93*	8.22	1.98
Finland	39.24*	9.04	2.10	Norway	43.82*	20.57*	5.43
France	39.74*	10.43	1.77	Portugal	25.46	8.79	3.57
Germany	40.96*	11.24	1.21	Spain	36.33*	11.71	1.50
Ireland	43.99*	15.97	5.94	Sweden	25.89	13.82	4.84
Italy	31.60	9.06	1.51	Turkey	36.67*	15.15	3.78
Japan	60.66*	13.50	1.84	UK	30.31	9.37	1.82
$\overline{Trace}$	41.47	12.08	3.13	$\overline{zzz}$	13.71*	1.42	-0.19

* Indicates significant at the 5 percent level.

Now we estimate the actual cointegrating vectors by using the method of dynamic OLS, since we have only one cointegrating vector for each country. According to the dynamic OLS, the cointegrating vector for each country can be estimated by regressing the real exchange rate of that country on the corresponding levels of productivity gap and oil price, in addition to the lagged and future values of the first differences of the same variables. The estimated cointegrating vectors are presented in Table 4. Our results demonstrate that the real exchange rate is positively and significantly related to both the productivity gap and the price of oil. These findings thus lend strong support to the Balassa-Samuelson effect, at least in the context of the OECD countries.

Table 4. Cointegrating Vectors (Dependent Variable = Real Exchange Rate)

Country	**Constant**	**Productivity Gap**	**Oil Price**	**Country**	**Constant**	**Productivity Gap**	**Oil Price**
Australia	-0.22	-1.67*	0.09	S Korea	-0.18*	0.20*	0.03
Belgium	0.07	0.95*	0.13*	Luxemburg	0.05	0.21*	0.06*
Canada	0.10	0.03	0.08*	Netherlands	0.06	0.70*	0.07*
Denmark	0.24*	0.82*	0.05	N Zealand	-0.23	-0.62	0.12
Finland	0.19*	0.33*	0.02	Norway	0.41*	-0.18	0.08*
France	0.05	0.34	0.01	Portugal	0.82*	1.87*	0.18*
Germany	0.08*	1.13*	0.04	Spain	0.14	0.84*	0.14*
Ireland	0.11*	0.31*	0.07*	Sweden	0.14*	-2.04*	0.03
Italy	0.14	0.75*	0.16*	Turkey	-0.96*	-0.71*	0.29*
Japan	0.75*	1.62*	-0.08*	UK	0.42*	1.83*	0.09*

* Indicates significant at the 5 percent level.

IV. Limitations and Recommendations for Future Research

Given the importance of the long run purchasing power parity, it is not surprising that substantial time and effort have been devoted to testing its empirical validity, using a host of unit root tests. As more powerful econometric techniques have recently emerged, the application of the related unit root tests has come to increasingly rely on less restrictive assumptions about the underlying data.

This paper has advanced the empirical literature on the long run PPP by using the more powerful panel unit root tests, which take account of the economic interactions among the member OECD countries. Finding unit roots in the real exchange rates of the sample countries, the paper has also used the related panel cointegration tests to account for the deviations of the real exchange rates from their purchasing power levels. At the same time, however, the paper is limited by the fact that it ignores the presence of major structural breaks, such as the 2008 financial crisis, during the sample period. Our findings are also relevant in the context of the OECD countries.

To address these limitations, it is therefore recommended that future research in this area be focused on testing for panel integration and cointegration in the presence of structural breaks in the underlying data (e.g., Li, Qian, and Su, 2016). In addition, it is also recommended that the empirical methodology employed in this paper be applied in the context of other non-OECD countries and regions of the world. Such additional empirical work can shed better lights on the long run validity of the PPP.

V. Conclusion

In this paper we examine the presence of unit roots in the real exchange rates of 20 OECD countries from 1970 to 2020, using the heterogeneous panel unit root tests developed by Im, Pesaran and Shin (2003) and Pesaran (2007). Given the presence of cross-sectional dependence across the panel, we find evidence of unit roots in the real exchange rates, thus rejecting their mean reversion for all the sample countries. We apply a series of countegration tests to explain the observed deviations of these real exchange rates from their long run purchasing power parities. Based on these tests, the OECD real exchange rates are mostly related positively to both the existing national productivity gaps and the movements of oil prices. Thus, we provide additional support for the Balassa-Samuelson effect, in which the real exchange rates of the higher income countries tend to be systematically overvalued, as hypothesized by Balassa (1964) and Samuelson (1964). Our findings thus demonstrate that the real exchange rates of the OECD countries have only limited tendency to automatically revert to their equilibrium values, a fact that will necessitate the adoption of coordinated policy actions by these countries to address any disequilibria in their mutual foreign account balances. One sure way to achieve this objective is to ensure that the adopted economic policies help expedite the pace of economic convergence among the OECD countries. The lack of such convergence during the recent financial crisis was a leading factor in pressuring the balance of international payments for the less industrially advanced countries within the OECD.

References

Adler, M. and B. Lehmann. 1983. "Deviations from Purchasing Power Parity in the Long Run." *Journal of Finance*, 38:1471-1487.

Akaike, H. 1973. "Information Theory and an Extension of the Maximum Likelihood Principle." Second International Symposium on Information Theory: Akademiai Kiado: 267-281.

Bai, J. and Ng, S. 2003. "Determining the Number of Factors in Approximate Factor Models." *Econometrica* 70:191-221.

Balassa, B. 1964. "The Purchasing Power Parity Doctrine: A Reappraisal." *Journal of Political Economy* 72: 584-596.

Balke, N.S. and T.B. Fomby. 1997. "Threshold Autoregression." *International Economic Review* 38: 627-645.

Baum C., J. Barkoulas, and M. Caglayan. 1999. "Long Memory of Structural Breaks: Can Either Explain Nonstationary Real Exchange Rates under the Current Float? *Journal of International Financial Markets, Institutions, and Money*9 (4), 359-376.

Breitung, J. 2005. "A Parametric Approach to the Estimation of Cointegration Vectors in Panel Data." *Econometric Reviews*: 151-173.

Breusch, T.S. and Pagan, A. 1980. "Lagrange Multiplier Test and Its Applications to Model Specification in Econometrics."*Review of Economic Studies*47: 139-153.

Cheung, Y.-W. and K. S. Lai. 2000. "On the Purchasing Power Parity Puzzle." *Journal of International Economics*52: 321-330.

http://ijbe.ielas.org/index.php/ijbe/index
ISSN (online) 2545-4137

Choi, I. 2001. "Unit Root Tests for Panel Data." *Journal of International Money and Banking*20 (2): 249-272.

Dickey, D. A. and W. A. Fuller. 1979. "Distribution of the Estimators for Autoregressive Time Series with a Unit Root." *Journal of the American Statistical Association* 74: 427-431.

Enders, W. and C.W. Granger. 1998. "Unit Root Tests and Asymmetric Adjustment with an Example Using the Term Structure of Interest Rates." *Journal of Business and Economic Statistics* 16: 304-311.

Engel, K.S. 2000. "One-Parameter Semigroups for Linear Evolution Equations," Springer.

Fama, E. 1991. "Efficient Markets II." *Journal of Finance* 46: 1575-1617.

Flores, R., P. Jorion, P.-Y. Preumont, and A. Szafarz .1999. "Multivariate Unit Root Tests of the PPP Hypothesis." *Journal of Empirical Finance* 6 (4): 335-353.

Frankel, J.A. and A.K. Rose. 1996. "A Panel Project on Purchasing Power Parity: Mean Reversion within and Between Countries." *Journal of International Economics* 40: 209-224.

Fraser, P., M. P. Taylor, and A. Webster. 1991. "An Empirical Examination of Long-Run Purchasing Power Parity as Theory of International Commodity Arbitrage." *Applied Economics 23* (11): 1749-1759.

Hsiao, C. 2007. "Panel Data Analysis: Advantages and Challenges." Invited Paper, Sociedad de Estadística e Investigación Operativa, 1-22.

Im, K., Pesaran, H, and Shin, K. 2003. "Testing for Unit Roots in Heterogeneous Panels." Journal of Econometrics 115: 53-74.

Johansen, S. 1991. "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models." *Econometric*a, 59 (6): 1551-1580.

Kapetanios, G.,Y. Shin, and S. Snell. 2002. "Testing for a Unit Root in the Nonlinear STAR Framework," *Journal of Econometrics* 112(2): 359-379.

Kugler, P. and C. Lenz. 1993. "Multivariate Cointegration Analysis and the Long-Run Validity of PPP." *Review of Economics and Statistics* 75 (1): 180-184.

Kydland F.E. and E.C. Prescott. 1982. "Time to Build and Aggregate Fluctuations," *Econometrica* 50: 1345-1370.

Larsson, R., Lyhagen, J. and M. Löthgren. 2001. "Likelihood-based cointegration tests in heterogeneous panels." *The Econometrics Journal* 4: 109-142.

Levin, A., Lin, F. 1992. "Unit Root Tests in Panel Data: Asymptotic and Finite Sample Properties." Unpublished Manuscript, University of California at San Diego, Discussion Paper No. 92-93 (revised 1993).

Li, D, J. Qian, and L. Su. 2016. "Panel Data Models with Interactive Fixed Effects and Multiple Structural Breaks," Journal of the American Statistical Association, 111 (516), 1804-1819.

Lothian, J. and M.P. Taylor. 1996. "Real Exchange Rate Behavior: The Recent Float from the Perspective of the Past Two Centuries." *Journal of Political Economy* 104 (3): 488-509.

Maddala, G.S. 1998. "Recent Developments in Dynamic Econometric Modelling: A Personal Viewpoint," Political Analysis.

Maddala, G.S. and Wu, S. 1999. "A Comparative Study of Unit Root Tests with Panel Data and a New Simple Test." *Oxford Bulletin of Economics and Statistics* 61: 631-652.

Mark, N. 1990. "Real and Nominal Exchange Rates in the Long Run: An Empirical Investigation." *Journal of International Economics* 28: 115-136.

MacDonald, R. 1996. "Panel Unit Root Tests and Real Exchange Rates." *Economics Letters* 50 (1): 7-11.

Moon, H. R. and B. Perron. 2004 "Testing for a Unit Root in Panels with Dynamic Factors. "*Journal of Econometrics* 122: 81-126.

O'Connell, P.G. 1998. "The Overvaluation of Purchasing Power Parity." *Journal of International Economics* 44: 1-19.

Oh, K.Y.1996. "Purchasing Power Parity and Unit Root Tests Using Panel Data" *Journal of International Money and Finance*15: 405-418.

Perron, P. 1989. "The Great Crash*, the Oil* Price Shock, and the Unit Root Hypothesis" *Econometrica* 57: 1361-1401.

Pesaran, H. 2004. "General Diagnostic Tests for Cross Section Dependence in Panels." *Cambridge Working Papers in Economics* No 435*.*

Pesaran, H. 2007. "A Simple Panel Unit Root Test in the Presence of Cross Section Dependence." *Journal of Applied Econometrics*, 22: 265–312.

Phillips, P. and Sul, D. 2003. "Dynamic Panel Estimation and Homogeneity Testing under Cross Section Dependence." *Econometric Journal* 6: 217-259.

Quah, D. 1994. "Exploiting Cross Section Variation for Unit Root Inference in Dynamic Data."*Economic Letters* 44: 9-19.

Reinsel, G. and Ahn, S. 1992. "Vector Autoregressive Models with Unit Roots and Reduced Rank Structures: Estimation, Likelihood Ratio Test, and Forecasting." *Journal of Time Series Analysis* 13: 353-357.

Rogoff, K. 1996. "Monetary Models of Dollar/Yen/Euro Nominal Exchange Rates: Dead or Undead?" *Economic Journal* 109 (459): 655-659.

Roll, R. 1979. "Violations of Purchasing Power Parity and their Implications for Efficient International Commodity Markets." in Marshall Sarnat and Giorgio Szego, eds. *International Finance and Trade*, (Ballinger, Cambridge, MA).

Samuelason, P. 1964. "Theoretical Notes on Trade Problems." *Review of Economics and Statistics* 46: 145-154.

Sarno, L. and M. P. Taylor. 2002. "Purchasing Power Parity and the Real Exchange Rate." *International Monetary Fund Papers*, 49: 65-105.

Schotman, P.C. and H.K.van Dijk. 1991. "A Baysian Analysis the Unit Root in Real Exchange Rates." *Journal of Econometrics* 49: 195-238.

Taylor, M. P. 1988. "An Empirical Examination of Long-Run Purchasing Power Parity Using Cointegration Techniques." *Applied Economics* 20: 1369-1381.

Taylor, M. P. and P. McMahon. 1988. "Long-Run Purchasing Power Parity Using Cointegration Techniques." *Applied Economics* 20: 1369-1381.

Taylor, A.M. 2002. "A Century of Purchasing Power Parity." *Review of Economics and Statistics* 84 (1): 139-150.

Taylor, M.P. 2006. "Real Exchange Rates and Purchasing Power Parity: Mean-Reversion in Economic Thought." *Applied Financial Economics* 16 (1/2): 1-17.

Zivot E. and D.W. Andrews. 1992. "Further Evidence on the Great Crash, the Oil Price shock, and Unit Root Hypothesis." *Journal of Business and Economic Statistics* 10: 251-270.