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# Investigating smooth breaks in real exchange rates

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#### H I G H L I G H T S:

- 1. The paper investigates purchasing power parity for 7 Middle Eastern countries.
- 2. The window of study is January 1980 to August 2008.
- 3. The nonlinear Fourier function for testing stationarity is applied.
- 4. PPP is not valid for most of the countries except for Bahrain and Israel.

Article History	A B S T R A C T
Received: 06-11-2013	We investigate the validity of purchasing power parity of 7 Middle East countries over
Accepted: 16-12-2013	January 1980 to August 2008 by applying the stationary test with a nonlinear Fourier
Available online: 22-12-2013	function as proposed by Becker et al. (2006). This test allows us to study the presence of unknown smooth structural breaks and the stationarity of real exchange rates. The empirical results indicate that PPP is not valid for most of these Middle East countries
Keywords:	except the Bahrain and Israel.
Exchange Rate;	
Fourier Stationary Test;	
Nonlinearity;	
Purchasing Power Parity.	
IEL Classification:	

G11; G15; G02; G14.DOI: http://dx.doi.org/10.18533/jefs.v1i01.29© 2013 The Authors. This is an open access article under the terms of the Creative Commons Attribution License 4.0, which allows use, distribution and reproduction in any medium, provided the original work is properly cited.

## 1.0 Introduction

"Does purchasing power parity work?" has been a disputable empirical issue for decades while it has important implications in international macroeconomics. According to the basic theoretical idea of purchasing power parity (PPP), we can expect that the real exchange rate returns to a constant equilibrium value in the long-run since any price of an internationally traded good should be the same anywhere in the world. In other words, a stationary real exchange rate indicates the existence of a long-run relationship between nominal exchange rate, domestic and foreign prices, and then the PPP hypothesis holds. However, many studies have examined the PPP hypothesis and found the conflict results for the existence of PPP. For example, Huizinga (1987) rejects the random walk by showing the existence of a mean-reversion component in real exchange rate increments, and Abuaf and Jorion (1990) and Lothian and Taylor (1996) find evidence of mean reversion in real exchange rates. Moreover, the results obtained using panel unit-root tests by Wu (1996), Oh (1996) and Papell (1997) support long-run PPP. On the other hand, the empirical evidence of Adler and Lehmann (1983) fail to reject the hypothesis that real exchange rates follow a random walk. Bahmani-Oskooee and Rhee (1992) and Mahdavi and Zhou (1994) also fail to find the existence of a long-run relationship between nominal exchange rate and relative prices through the cointegration technique. Therefore, from these studies, we find that the PPP hypothesis still remains the open question.

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From the viewpoint of methodology, the Augmented DF (Dickey and Fuller, 1979), PP (Phillips and Perron, 1988) and KPSS (Kwiatkowski et al., 1992) tests have been mostly employed by recent studies of long-run PPP. However, Frankel (1986, 1990) argue that prior empirical studies employing these types of test on the PPP hypothesis may have low power to reject the null hypothesis of a unit root. Taylor and Taylor (2004) argue that using more years of data can solve the power problem, but brings a new problem that real factors may generate structure breaks or shifts in the equilibrium real exchange rate. Leaving out existing structural changes leads to a bias that increases the possibility to accept a false null hypothesis of a unit root (Perron, 1989). In fact, the exchange rates could be affected by internal and external shocks generated by structural changes and then have considerable short-run variations. The PPP hypothesis requires that the real exchange rate evolves around a constant, and thus it is critical to comprehend whether the real exchange rate has any tendency to stabilize at a long-run equilibrium level. If the stationarity of real exchange rate is found by using unit root test which allows for the possible presence of the structural break, the effects of shocks, which cause deviations around a mean value or deterministic trend, are only temporary. Then, PPP is valid in the long-run (Marcela et al., 2003; Narayan, 2005, 2006).

To mitigate the bias in the usual unit root tests without considering any structural break, prior studies for testing PPP hypothesis use a general method which includes dummy variables to account for one known or exogenous structural break (for example, Perron, 1989; Banerjee et al., 1992; Zivot and Andrews, 1992; Perron and Vogelsang, 1992; Perron, 1997; Lumsdaine and Papell, 1998). However, using dummy variables to capture structural breaks has three undesirable defects. First, it is a necessary to know the exact number and location of the breaks, but these are usually unknown and need to estimate their parameters. In turn, it brings a pre-selection bias (Maddala and Kim, 1998). Second, those traditional tests only take one or two breaks into account, implying that if exceed two breaks presenting in the data generating process, the bias in traditional unit root test still exists. Final, in terms of low frequency data, the structural changes take the form of large swings cannot be capture well by employing dummy variables which suggests sharp and sudden changes in the trend or level. Therefore, the breaks should be approximated as smooth and gradual processes (see Leybourne et al., 1998). These show that the means of Flexible Fourier transforms, developed by Becker et al. (2006), Enders and Lee (2009), and Christopoulos and Leon-Ledesma (2010), which model any structural break of an unknown form as a smooth process should be use to investigate the PPP hypothesis for avoiding these problems. Gallant (1981), Becker et al. (2004), Enders and Lee (2009), and Pascalau (2010) show that a Fourier approximation can often capture the behavior of an unknown function even if the function itself is not periodic, and they argue that their empirical framework requires only the specification of the proper frequency in the estimating equations. By reducing the number of estimated parameters, they ensure the tests to have good size and power irrespective of the time or shape of the break.

This paper makes several contributions to the related literature. First, the basic question of prior studies of PPP hypothesis is how to incorporate breaks of each time series into the cointegration framework, and thus we use the stationary test with a Fourier function, developed by Becker et al. (2006)<sup>1</sup>, to examine the validity of long-run PPP. Second, even though many studies provide evidences of PPP long-run equilibrium in industrialized economies or developing countries provided by Froot and Rogoff (1995), Bahmani-Oskooee and Mirzai (2000), Sarno and Taylor (2002), Kalyoncu (2009), there are few studies on the exchange rates of Middle East countries (for example, Narayan and Prasad, 2005). Therefore, we fill up the research gap on the validity of long-run PPP by using the Middle East countries as our sample. Final, our findings show that the PPP hypothesis does not hold true for most of this field of research by offering a potential explanation to the mixed results of previous related PPP studies, but also provide a reference to international investors and governments to decide their investment strategy and monetary policy.

This paper is organized as follows. Section 2 briefly describes the PPP. Section 3 introduces the stationary test with a nonlinear Fourier function proposed by Becker et al. (2006) and Section 4 presents the data used in our study and the empirical results. We summarize our conclusions in the last section.

## 2.0 The description of PPP

In theory, the concept of PPP is that the exchange rate adjusted price level in one country equal to the price level in the other country and implies that real exchange rate, which equals to the nominal exchange divided by the ratio of the two countries price levels, is treated as a constant. In this paper, we define the bilateral real exchange rate as the nominal exchange rate deflated by a ratio of foreign and domestic price levels:

$$R_t = E_t P_t^* / P_t \tag{01}$$

, Where  $R_t$  represents the real exchange rate;  $E_t$  represents the nominal exchanger defined in local currency units

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<sup>&</sup>lt;sup>1</sup> As the suggestion of Becker et al. (2006), KPSS-type stationarity tests are useful to confirm results from unit-root tests with a stationary alternative since tests with the null of a unit root have low power with stationary but persistent data.

per U.S. dollar (in our case);  $P_t$  and  $P_t^*$  represent the domestic and foreign price levels, and we use consumer price index (CPI) to be the proxies of price levels. By taking the logarithm both sides of the Eq. (1) and rearranging the terms yields the following equation.

$$r_t = e_t + p_t^* - p_t$$
 (02)

, Where  $r_t$  is the logarithm real exchange rate;  $e_t$  is the logarithm nominal exchanger defined in local currency units

per U.S. dollar;  $p_t$  and  $p_t^*$  are the logarithm domestic and foreign price levels. By investigating whether the real exchange rate series present a unit root, we can perceive that PPP does hold in the long-run or not. If the real exchange rate series have a unit root, PPP does not hold in the long-run. On the contrary, the hold of PPP implies that nominal exchange rate corrected for inflation differentials.

There are three distinct macroeconomic implications while the real exchange rates series are non-stationarity. First, if real exchange rate depreciates, it could bring a gain in international competitiveness, and thus shift the employment toward the depreciating country (Dornbusch, 1987). That proves that it is important to establish the empirical validity of the PPP theory. The other implication is the existence of arbitrage opportunity<sup>2</sup> which indicates arbitrager can buy the commodity cheaply in one location but sell it at a higher price in the other. Final, deviations of real exchange rate create exchange risk to international investors and great macroeconomic fragility to external shocks, which might end in severe currency and financial crisis (Ortiz et al., 2005).

## 3.0 Stationary test with a Fourier function

Traditional unit root tests that ignore structural change could fail to provide evidence of PPP when it actually holds outside of the structural shift. Therefore, Becker et al. (2006) employ a variant of the Flexible Fourier transform (i.e., Gallant 1981) to control the unknown nature of the breaks. The major advantage of Fourier function is that it can use only a small number of low frequency components to capture the essential characteristics of more structural breaks, because a break tends to shift spectral density function towards frequency zero. In particular, this test works best in the presence of breaks that are gradual and has good power to detect u-shaped and smooth breaks (Enders and Lee, 2011). Following the approach of Becker et al. (2006), we consider the data generating process:

$$y_t = \alpha_0 + \beta t + \gamma_1 \sin(2\pi kt/T) + \gamma_2 \cos(2\pi kt/T) + r_t + \varepsilon_t$$
(03)

, Where the  $r_t$  process is defined as:

$$r_t = r_{t-1} + u_t \tag{04}$$

;  $\mathcal{E}_t$  is stationary error, and  $u_t$  is independent and identically distributed with variance  $\sigma_u^2$ .

The process described by Eqs. (3) and (4) is stationary under the null hypothesis ( $\sigma_u^2 = 0$ ). The rational for selecting  $[\sin(2\pi kt/T), \cos(2\pi kt/T)]$  is based on the fact that a Fourier expression is capable of approximating absolutely integrable functions to any desired degree of accuracy, and the k of this equation represents the selected approximation frequency ( $k = 1, \dots, 5$ ). Furthermore,  $\gamma = [\gamma_1, \gamma_2]'$  measures the amplitude and displacement of the frequency component. The feature of Eq. (3) is that the standard linear specification emerges as a special case by setting  $\gamma_1 = \gamma_2 = 0$ . It also follows that at least one frequency component must be present if there is a structural break. We use F-test to examine the null hypothesis  $\gamma_1 = \gamma_2 = 0$ , and rejecting the null hypothesis implies that the series must have a nonlinear component. Becker et al. (2004) use this property of Eq. (3) to develop a test with more power for detecting breaks of an unknown form than the standard Bai and Perron (1998) test. As the data generating process in Eq. (3) nests the one used to generate the common KPSS test, the Becker et al.'s (2006) stationary test with a Fourier function needs only a slight modification of the KPSS statistic. First, we need to obtain the residuals from the following equations:

$$y_t = \alpha_0 + \gamma_1 \sin(2\pi kt/T) + \gamma_2 \cos(2\pi kt/T) + v_t \tag{05}$$

and

$$y_t = \alpha_0 + \beta t + \gamma_1 \sin(2\pi kt/T) + \gamma_2 \cos(2\pi kt/T) + v_t \qquad (06)$$

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<sup>&</sup>lt;sup>2</sup> Taylor and Taylor (2004) suggest that the PPP theory will hold at least approximately because of the possibility of international goods arbitrage, even though an extremely narrow class of products and presence of transactions costs limit arbitrage behaviors.

The major function of Eq. (5) is to examine the null of level stationarity while Eq. (6) is to investigate the null of trend stationarity. The test statistic is given by Eq. (7).

$$\tau_{\mu}(k) = \frac{1}{T^{2}} \frac{\sum_{t=1}^{T} \tilde{S}_{t}(k)^{2}}{\tilde{\sigma}^{2}}$$
(07)

, Where  $\widetilde{S}_{t}(k) = \sum_{j=1}^{t} \widetilde{v}_{j}$  and  $\widetilde{v}_{j}$  are the OLS residuals from Eqs. (5) and (6), respectively. As in the KPSS

framework and following the PP-type approach, Becker et al. (2006) suggests that a nonparametric estimate of  $\sigma^2$  can be obtained by choosing a truncation lag parameter *I* and a set of weights  $w_i$ , j = 1, 2, ..., l.

$$\sigma^2 = \tilde{\delta}_0 + 2\sum_{j=1}^l w_j \tilde{\delta}_j \tag{08}$$

, Where  $\tilde{\delta}_j$  is the *jth* sample autocovariance of the residuals  $\tilde{v}_t$  from equations (5) and (6), respectively. Becker et al. (2006) suggests that the optimal frequencies in Eqs. (5) and (6) should be obtained by minimizating the sum of squared residuals. Their Monte Carlo experiments propose that no more than one or two frequencies should be used because of the loss of power associated with a larger number of frequencies. Therefore, this study follows the method of Becker et al. (2006) to set the maximum frequencies (k=5) to obtain the optimal frequencies.

#### 4.0 Data and empirical results

#### 4.01 The description of data

Our empirical sample includes 7 Middle East countries: Bahrain, Israel, Jordon, Kuwait, Saudi Arabia, Syria, and Turkey. In this study, we use monthly data and the research time span is from January 1980 to August 2008. We obtain all consumer price indices (CPI, based on 2000 = 100) and nominal exchange rates relative to the USA dollar data from the International Monetary Fund's International Financial Statistics CD-ROM. The major reasons of examining for PPP against the USA are that international foreign exchange markets are mostly dollar dominated, and the USA is the major trading partner for these Middle East countries. Furthermore, we transform each of the consumer price indies and nominal exchange rate series into natural logarithms before engaging in the econometric analysis.

A summary of the statistics is shown in Table 1, and we find that the Jarque-Bera test results indicate that all the bilateral log real exchange rate data sets are approximately non-normal. Furthermore, in these Middle East countries, the Syria/USD with value varying from -2.041 to -2.549 and a standard deviation of 0.312 is the most volatile currency, while the Kuwait/USD with values varying from 1.147 to 1.454 and a standard deviation of 0.075 is the least volatile currency.

#### 4.02 Results from the stationary test with a Fourier function

We employ several traditional unit root tests to examine the null of a unit root in bilateral real exchange rates for 7 Middle East countries. The results of unit root tests are reported in Table 2 and the results of ADF, PP and ADF-GLS tests show that Bahrain, Israel, Syria, and Turkey are fail to reject the null of a unit root for real exchange rates. The results of KPSS test exhibit the real exchange rates are non-stationary in all countries. According to the interpretation of Taylor and Taylor (2004), there is the presence of real effects on the equilibrium real exchange rate (the Harrod-Balassa-Samuelson effect) and implies that real exchange rates may exhibit the time trend. Therefore, we further investigate whether time trend presents in each Middle East countries. The results in Table 2 show that all the tests of time trend present are not significant, except the Bahrain. This implies that the time trend exists in the real exchange rate of Bahrain, thus we add the time trend into the stationary test with a Fourier function for Bahrain.

To examine the presence of structural changes in the real exchange rate, we employ the stationary test with a Fourier function. Before engaging in the stationary test with a Fourier Function, we first need to find the best frequency by using a grid-search while there is no a priori knowledge concerning the shape of the breaks in the data. Therefore, we estimate Eq. (5) for each integer  $k = 1, \dots, 5$  according to the recommendations provided by Enders and Lee (2004) which is a single frequency can capture a wide variety of breaks. We can find that the sum of squared residuals (SSRs) in Table 3 support that a single frequency works best for most of the series, with the

exception of Turkey. Furthermore, the results of F-test reject the null hypothesis and imply that it is reasonable for considering the Fourier function into the model.

Table 3 also displays the results of stationary test with a nonlinear Fourier function based on the estimated frequencies. Here, we follow Burke (1994) to use a 10% significance level, and choose a lag of 12 for the truncation lag. The results in this table show that the null hypothesis is rejected in favor of the alternative hypothesis for most of the cases, with the exception of Bahrain and Israel. We infer the behind reason of these empirical findings is that transactions costs in these countries may be high such that arbitrage may not be profitable for small price differentials only. Furthermore, hard peg, weak goods market arbitrage, and the dollar volatility induce the persistent deviation from PPP (Hassanain, 2004).

The stationary test with a Fourier function employed in our study evidently provide weak evidence to approve the validity of PPP in the long-run for 7 Middle East countries, and these results are consistent with that of Drine and Rault (2008). However, the exchange rates might be affected by internal and external shocks generated by structural changes, and then considering structural changes in the data generating process will increase the test power so that our results are contrary to the results found by Bahmani-Oskooee (1998), Hassanain (2004), Narayan and Prasad (2005) which favor the validity of PPP for most of the Middle East countries. The major policy implication from these empirical findings is that Bahrain and Israel governments can use PPP to predict exchange rate that determine whether a currency is over or undervalued and experiences difference between domestic and foreign inflation rates, and this implies that investors can not earn excess profit form arbitrage. On the contrary, obtaining gains from arbitrage in traded goods is possible in the other six countries due to the invalidity of PPP for these countries.

The empirical results have been documented the presence of structural changes in the real exchange rate. This observation also presented in the Figure 1. We can clearly observe the time paths of the real exchange rates where a positive change in the real exchange rate indicates real depreciation. Consequently, it is rational to allow for structural breaks in testing for a unit root (and/or stationary), and we infer that most of structural breaks, which are associated with the change in monetary policies and financial crisis, result the level of PPP equilibrium to change (Breitung and Candelon, 2005). Furthermore, the stationary test with Fourier function allows us to investigate the nonlinear smooth adjustment in real exchange rates. In order to compare with the stationary test with Fourier function, we also use the nonlinear SURKSS test employed by Wu and Lee (2009) to examine the nonlinear properties of long-run PPP for Middle East countries. The results of SURKSS tests reported in Table 4 and show that real exchange rates of 4 Middle East countries are stationary after allowing for nonlinear adjustment process. These results are different with the results of Table 3 and the reason is that the stationary test with Fourier test not only allow the presence of structural breaks but also capture the nonlinear smooth adjustment in real exchange rates. Therefore, the PPP may not hold in most Middle East countries when we consider both nonlinear smooth adjustment and the presence of structural breaks in real exchange rates of Middle East countries.

### 5.0 Conclusions

As discussed by Becker et al. (2006), the stationary test with a Fourier function has ability to investigate unit roots in the presence of various types of smooth structural breaks with an unknown form. Furthermore, the Flexible Fourier transform introduced by Gallant (1981) can capture the unknown shape of the breaks and the Monte Carlo simulations of Becker et al. (2006) show that the test does not suffer from low power and have good size properties. As a result, we use this test to investigate the validity of PPP for 7 Middle East countries during the period from January 1980 to August 2008. We find that PPP does not hold for most of Middle East countries, except for Bahrain and Israel. The empirical results bring important policy implications to governments of 7 Middle East countries, that is, only Israel country can use PPP to determine the equilibrium exchange rate.

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Table 01: Summary statistics								
Countries	Mean	Max.	Min.	Std. Dev.	Skew.	Kurt.	JB.	
Bahrain	1.152	1.533	0.838	0.209	0.373	1.882	25.281***	
Israel	-1.448	-1.237	-1.808	0.121	-0.570	2.954	18.227***	
Jordon	0.474	0.958	0.314	0.179	1.002	2.494	59.802***	
Kuwait	1.255	1.454	1.147	0.075	0.673	2.484	29.122***	
Saudi Arabia	-1.128	-0.511	-1.455	0.251	0.779	2.661	35.624***	
Syria	-2.549	-2.041	-3.196	0.312	-0.574	1.922	34.736***	
Turkey	0.481	1.141	-0.005	0.249	0.738	3.084	30.600***	

Notes: The sample period is from Jan. 1980 to Aug. 2008. \*\*\*, \*\*, and \* indicate significance at the 0.01, 0.05 and 0.1 levels, respectively.

Table 02: Conventional unit root test									
-			Le	evel		First Different			
	<i>t</i> -stat for time Trend	ADF	ADF-GLS	РР	KPSS	ADF	ADF-GLS	РР	KPSS
Bahrain	-1.886*	-0.899(0)	2.296(0)	-0.913(18)	2.465[15]** *	- 21.99(0)***	-0.549(12)	-22.27(13)***	0.114[18]
Israel	0.764	-2.379(0)	- 2.385(0)**	-2.118(7)	0.408[15]*	- 21.29(0)***	-0.999(5)	-21.61(9)***	0.076[14]
Jordon	0.369	-2.802(0)*	0.032(0)	- 2.806(10)*	1.573[15]** *	- 20.72(0)***	- 3.422(4)** *	-20.59(10)***	0.596[10]**
Kuwait	0.369	-2.785(0)*	-0.577(1)	-2.747(6)*	1.541[15]** *	- 21.29(0)***	- 3.804(4)** *	-21.14(5)***	0.339[4]
Saudi Arabia	-0.675	4.66(3)***	2.634(1)	4.76(7)***	2.049[15]** *	- 15.39(0)***	-0.926(10)	-15.44(2)***	1.353[5]***
Syria	1.347	-2.152(0)	0.538(2)	-2.138(3)	1.591[15]**	-	-0.835(11)	-18.71(2)***	0.048[1]

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					*	18.71(0)*	**				
Turkey	-0.518	-2.517(0)	-0.953(0)	-2.526(6)	0.643[15]* *	* <u>-</u> 18.21(0)*	- ** 17.66(	0)** -18	.27(11)***	* 0.392[10	)]*
Note: 1.	The nu	mber in pai	rentheses i	indicates th	e selected	lag orders.	Lags are	chosen	based or	n Campbell	and

- Perron(1991).2. The number in brackets indicates the selected lag truncation for the Bartlett kernel, as suggested by the New-West(1987) test.
- 3. \*, \*\* and \*\*\* indicate significance at the 10%, 5% and 1% level,, respectively.

		5			
Countries	Sum of Square Residuals (SSR)	$\hat{k}$	$F_{\mu}(\hat{k})$	$ au_{\mu}(\hat{k})$	$ au_{\mu KPSS}$
Bahrain	0.274	1	8955.285***	0.089	2.465[15] ***
Israel	2.532	1	169.638***	0.101	0.408[15] *
Jordon	4.226	1	267.976***	0.749***	1.573[15] ***
Kuwait	0.871	1	204.869***	0.478***	1.541[15] ***
Saudi Arabia	10.982	1	157.066***	1.004***	2.049[15] ***
Syria	11.911	1	282.873***	0.674***	1.591[15] ***
Turkey	12.105	2	123.781***	0.733***	0.643[15] ***

Table 03: Stationary test with a nonlinear Fourier function

Notes:  $F_{\mu}(\hat{k})$  is value of F-test and to examine whether both  $\gamma_1$  and  $\gamma_2$  equal to zero;  $\tau_{\mu}(\hat{k})$  represents the t-test value;  $\tau_{\mu KPSS}$ 

provides

the results of the KPSS test. \*\*\*, \*\*, and \* indicate significance at the 0.01, 0.05 and 0.1 levels, respectively.

Table 04. SURKSS unit root test							
	CUDVCC	ß	Critical value				
Countries	30KK33	$\rho$	1%	5%	10%		
Bahrain	-0.887	-0.0015	-3.143	-2.533	-2.214		
Israel	-2.359**	-0.0046	-2.529	-1.882	-1.538		
Jordon	-3.168**	-0.0178	-3.243	-2.692	-2.371		
Kuwait	-2.456**	-0.0055	-2.500	-1.815	-1.454		
Saudi Arabia	-4.193***	-0.0020	-2.685	-2.006	-1.626		
Syria	-1.371	-0.0003	-3.282	-2.681	-2.330		
Turkey	-0.960	-0.0115	-3.443	-2.841	-2.529		

Notes: \*\*\*, \*\*, and \* indicate significance at the 0.01, 0.05 and 0.1 levels, respectively. Critical values are calculated by Monte Carlo simulation with 10,000 draws, tailored to the present sample size.

Figure 01: ln(Real Exchange Rates) and Fourier function for 7 Middle East countries (US Dollar Based)



