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Empirical investigation of purchasing power parity for Turkey: Evidence from recent nonlinear unit root tests

Dilem Yıldırım

Department of Economics, Middle East Technical University, 06531, Ankara, Turkey

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A B S T R A C T

This study explores the empirical validity of the purchasing power parity (PPP) hypothesis between Turkey and its four major trading partners, the European Union, Russia, China and the US. Accounting for the nonlinear nature of real exchange rates, we employ a battery of recently developed nonlinear unit root tests. Our empirical results reveal that nonlinear unit root tests deliver stronger evidence in favour of the PPP hypothesis when compared to the conventional unit root tests only if nonlinearities in real exchange rates are correctly specified. Furthermore, it emerges from our findings that the real exchange rates of the countries having a free trade agreement are more likely to behave as linear stationary processes.

1. Introduction

The Purchasing power parity (PPP) hypothesis is one of the most explored issues in international macroeconomics. The PPP hypothesis postulates that the nominal exchange rate between two national currencies should adjust to changes in the price levels of the two countries, keeping the real exchange rate unchanged. The basis of the PPP theory is the law of one price (LOOP), which states that, the price of a commodity or a bundle of commodities should be equal across countries when expressed in terms of a common currency. Due to factors like transaction costs, imperfect competition, taxation, subsidies and trade barriers, PPP might not hold in the short-run. However, given that international goods market arbitrage should be traded away over time, PPP is expected to hold in the long run. This implies that the real exchange rate is expected to return to a constant equilibrium value in the long run. The validity of PPP is critical to empirical researchers and policy makers for several reasons. As stated in Holmes (2001) and Sarno (2005), PPP is employed to predict the exchange rate and specify whether a currency is over or undervalued. This is particularly important for less developed countries and countries experiencing large differences between domestic and foreign inflation rates. PPP is also an indispensable building block of many important theoretical open economy models and its violation might cast doubts on the validity of these models (Rogoff, 1996; Taylor, 1995). Finally, it is used to set exchange rate parities, compare national income levels and establish the degree of misalignment of the nominal exchange rate.

There are voluminous studies available on the empirical validity of the long-run PPP. A major strand of this literature examines its validity by testing for stationarity of real exchange rates, as stationarity implies mean reversion and, hence, PPP. In this sense, earlier studies test PPP in a linear context employing conventional unit root tests. Most of these studies, however, fail to provide empirical evidence in favour of real exchange rate stationarity (e.g. Meese and Rogoff, 1988; Edison and Fisher, 1991). Glen (1992), Lothian and Taylor (1996), Oh (1996) and Wu (1996), amongst others, ascribe this failure to the low power displayed by conventional unit root tests and attempt to address the power problem

E-mail address: dilem@metu.edu.tr.
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through the use of long span data sets and panel unit root tests. Although more supportive results are reported from long span and panel data studies, they fall under the criticisms of Frankel and Rose (1996), Hegwood and Papell (1998), Taylor and Sarno (1998) and Taylor (2003). Frankel and Rose (1996) and Hegwood and Papell (1998) argue that very long time series could be exposed to structural breaks, which might produce spurious results. On the other hand, Taylor and Sarno (1998) and Taylor (2003) argue that testing PPP using panel unit root tests may entail some problems due to the heterogeneity issue. Ignoring country specific differences and expecting real exchange rates to have same dynamics for all countries in the sample, might lead to unreliable inferences on the validity of PPP. Moreover, rejecting the null hypothesis of unit root in a panel data implies that at least one of the series is mean reverting, but not that all the series under consideration are stationary. Hence, no consensus has emerged regarding stationarity of the real exchange rate and whether real exchange rate is stationary or not remains contentious in the linear framework.[1]

The idea that real exchange rate series may follow a nonlinear pattern has been put forward by the theoretical models of Dumas (1992) and Sercu et al. (1995). In these models, it is demonstrated that transaction costs might create a no trade band, within which the real exchange rate may follow a (near) random walk process, as the arbitrage is not large enough to cover transaction costs. However, once the real exchange rate hits the band, which is the case of an overvalued or undervalued exchange rate, arbitrage becomes profitable, international trade takes place, and hence the real exchange rate turns to a stationary process. This suggests that the real exchange rate might follow a globally stationary nonlinear process with a (near) unit root behaviour around PPP equilibrium replaced by a stationary behaviour when deviations from PPP become large. Recognizing the low power of conventional unit root tests in detecting stationarity of real exchange rates with such nonlinear dynamics due to Pippenger and Goering (1993) and Taylor (2001), a growing literature has emerged, which accommodates no-arbitrage and profitable arbitrage dynamics of real exchange rates in an exponential smooth transition autoregressive (ESTAR) model.

In this context, Kapetanios et al. (2003) propose an ESTAR type unit root test, which is designed specifically on the basis of the no arbitrage versus profitable arbitrage argument of Dumas (1992) and Sercu et al. (1995). Recently, the test of Kapetanios et al. (2003) has gained momentum in testing real exchange rate stationarity, with several applications, including Liew et al. (2004), Hasan (2004), Chortareas and Kapetanios (2004), Ceratto and Sarantis (2006), Francis and Iyare (2006), Wallace (2008), Cuestas and Gil-Alana (2009) and Telatar and Hasanov (2009). Compared to the previous studies using conventional unit root tests, these studies provide stronger evidence of stationarity of real exchange rates for a broad range of developing and developed countries. They almost uniformly indicate that the empirical evidence in favour of stationarity increases when nonlinearities in real exchange rates are explicitly accommodated. Most recently, Kılıç (2011) and Kruse (2011) propose modified versions of the nonlinear unit root test of Kapetanios et al. (2003) to examine stationarity of real exchange rates for OECD countries and the European Union, respectively. Both studies observe that their modified tests reveal more evidence in favour of PPP compared to the unit root test of Kapetanios et al. (2003).

Our study aims to investigate the empirical validity of the PPP hypothesis between Turkey and its four major trading partners, the European Union, Russia, China and the US. Existing studies on the validity of PPP for Turkey deliver rather mixed results. Within a linear context, Telatar and Kazdagli (1998) finds no evidence in favour of stationarity of Turkish real exchange rates through the standard cointegration tests over the period 1980(10)-1993(10). Similarly, using the conventional unit root tests for a sample period of 1980Q1-2005Q4, Kalyoncu (2009) reports nonstationarity of Turkish real exchange rates with respect to the currencies of its all major trading partners except the UK. Guloglu et al. (2011) and Gozgor (2011), however, observes that PPP holds for Turkey when applying linear panel unit root tests to the samples of period 1991(1)-2008(3) and 2003(1)-2010(12), respectively. In a nonlinear framework, on the other hand, Alba and Park (2005) deliver rather mixed empirical evidences through a threshold autoregressive (TAR) type unit root test over the period 1973(1)-2004(9). They observe that the real exchange rate follows a stationary process in one-regime and a nonstationary process in the other regime, with most of the observations falling into the nonstationary regime. Using an ESTAR type nonlinear cointegration test, on the other hand, Ozdemir (2008) provides only weak empirical evidence for PPP for the period 1984(1)-2004(1), while Erlat (2004) finds stronger empirical support for stationarity of real exchange rates by adopting the ESTAR type unit root test of Kapetanios et al. (2003) for the period 1984(1)-2000(9).

The lack of consensus on the empirical validity of PPP provides a room to investigate further the behaviour of Turkish real exchange rates within the context of recent developments in unit root tests. In this sense, taking the possible nonlinear nature of real exchange rates into consideration, we utilize unit root testing procedures that account for ESTAR type nonlinearity, as in many recent studies. However, rather than being confined to a single nonlinear testing procedure, which is the case in all existing PPP studies on Turkey, we adopt a battery of newly developed nonlinear approaches. It is the aim of the study to provide a more comprehensive insight into the real exchange rate stationarity and nonlinearity. As such, we employ the recently proposed nonlinear unit root tests of Kılıç (2011) and Kruse (2011) along with the commonly applied unit root test of Kapetanios et al. (2003).

The rest of the paper is organized as follows. The next section describes the econometric methodology we utilize. The data and the empirical results are then reported in Section 3, with concluding comments in Section 4.

2. Methodology

This section describes, respectively, the nonlinear unit root tests of Kapetanios et al. (2003), Kruse (2011) and Kılıç (2011) within the context of the PPP hypothesis.

2.1. Nonlinear unit root test of Kapetanios et al. (2003)

Kapetanios et al. (2003) develop a procedure to test for nonstationarity against a globally stationary nonlinear ESTAR process defined as:

$$\Delta\tilde{q}_t = \rho\tilde{q}_{t-1}F_E(\tilde{q}_{t-1};\gamma) + \sum_{i=1}^{p}\lambda_i\Delta\tilde{q}_{t-i} + \varepsilon_t \quad (1)$$

where $\tilde{q}_t$ denotes the de-meaned real exchange rate, p is the required number of lagged changes of $\Delta\tilde{q}_t$ that ensures an iid structure for the error term, ε_t, and $F_E(\tilde{q}_{t-1};\gamma)$ is the symmetrically U-shaped exponential transition function such that

$$F_E(\tilde{q}_{t-1};\gamma) = \left(1 - \exp\left(-\gamma\tilde{q}_{t-1}{}^2\right)\right) \quad (2)$$

[1] See Rogoff (1996), Sarno and Taylor (2002) and Taylor and Taylor (2004) for extensive reviews of the PPP literature.

where $\tilde{q}_{t-1}$ is the transition variable, $\gamma \geq 0$ is the slope parameter. In this framework, testing a unit root against nonlinear stationarity is equivalent to testing the null hypothesis of $\gamma = 0$ against the alternative of $\gamma > 0$. Under the null hypothesis, the real exchange rate displays linear unit root behaviour. Under the alternative, however, it follows a globally stationary ESTAR process, provided that $-2 < \rho < 0$, which is assumed to hold. More specifically, under the alternative of $\gamma > 0$, the real exchange rate displays a unit root behaviour in the middle regime ($F_E(\tilde{q}_{t-1}; \gamma) \approx 0$) where deviations from the zero attractor are very small. However, once deviations become large enough to push the real exchange rate towards the outer regime ($F_E(\tilde{q}_{t-1}; \gamma) \approx 1$), where arbitrage opportunities arise, it turns to a stationary process with a tendency to converge back to the zero attractor.

Testing the null hypothesis of $\gamma = 0$, however, is subject to the criticism of Davies (1987) since ρ is unidentified under the null. The nuisance parameter problem is overcome by replacing the exponential transition function in (2) with its first-order Taylor series approximation around $\gamma = 0$ and this yields the auxiliary regression:

$$\Delta\tilde{q}_t = \delta\tilde{q}_{t-1}{}^3 + \sum_{i=1}^{p} \lambda_i \Delta\tilde{q}_{t-i} + \upsilon_t \tag{3}$$

where the null hypothesis of $\gamma = 0$ turns to the null of $\delta = 0$ with the alternative of $\delta < 0$. Kapetanios et al. (2003) show that the asymptotic distribution of the t-statistic for $\delta = 0$, denoted by t_{NL}, is non-standard and tabulate the asymptotic critical values of the t_{NL} statistic via stochastic simulations.

2.2. Nonlinear unit root test of Kruse (2011)

Kruse (2011) extends the unit root test of Kapetanios et al. (2003) by allowing for the possibility that the real exchange rate may revert to an equilibrium value different from zero. More specifically, considering the case where the degree of mean reversion of the real exchange rate depends on the distance of the lagged real exchange rate from an unknown nonzero attractor (c), Kruse (2011) reforms the model (1) by using the exponential transition function:

$$F_E(\tilde{q}_{t-1}; \gamma) = \left(1 - \exp\left(-\gamma(\tilde{q}_{t-1} - c)^2\right)\right) \tag{4}$$

As in Kapetanios et al. (2003), the null and alternative hypotheses are set as $H_0 : \gamma = 0$ and $H_1 : \gamma > 0$. A first-order Taylor series approximation around $\gamma = 0$ is applied to circumvent the nuisance parameter problem and the following modified ADF regression is obtained:

$$\Delta\tilde{q}_t = \delta_1\tilde{q}_{t-1}{}^3 + \delta_2\tilde{q}_{t-1}{}^2 + \sum_{i=1}^{p} \lambda_i \Delta\tilde{q}_{t-i} + \upsilon_t \tag{5}$$

In this representation, the null hypothesis of $\gamma = 0$ turns to the null of $\delta_1 = \delta_2 = 0$ with the alternative hypothesis of $\delta_1 < 0,\ \delta_2 \neq 0$, where two-sidedness of δ_2 stems from the fact that the location parameter (c) is allowed to take nonzero values. Obviously, a standard Wald test is not appropriate to test this joint null hypothesis against the alternative where one parameter is one-sided while the other one is two-sided. Therefore, following Abadir and Distaso (2007), Kruse (2011) proposes a modified Wald statistic τ as:

$$\tau = t^2{}_{\delta_2{}^\perp = 0} + 1\left(\hat{\delta}_1 < 0\right) t^2{}_{\delta_1 = 0}$$

where $t^2{}_{\delta_2{}^\perp = 0}$ represents the squared t-statistic for the hypothesis $\delta_2{}^\perp = 0$ with $\delta_2{}^\perp$ being a transformed form of δ_2 that is orthogonal to δ_1, $t^2{}_{\delta_1 = 0}$ is the squared t-statistic for the hypothesis $\delta_1 = 0$ and the indicator function 1(.) stands for one-sidedness of δ_1 under the alternative hypothesis.[2] The τ statistic has a non-standard asymptotic distribution and the asymptotic critical values are provided by Kruse (2011).

2.3. Nonlinear unit root test of Kılıç (2011)

The unit root test proposed by Kılıç (2011) is similar to that of Kapetanios et al. (2003), with the differences being due to the choice of the transition variable, the setup of the null hypothesis and the way of dealing with the nuisance parameter problem. Kılıç (2011) considers the case where nonlinearities in real exchange rates are driven by the size of currency appreciation (depreciation) and reformulates model (1) by replacing the transition variable $\tilde{q}_{t-1}$ with $\Delta\tilde{q}_{t-1}$ as

$$\Delta\tilde{q}_t = \rho\tilde{q}_{t-1} F_E(\Delta\tilde{q}_{t-1}; \gamma) + \sum_{i=1}^{p} \lambda_i \Delta\tilde{q}_{t-i} + \varepsilon_t \tag{6}$$

Utilization of the lagged difference term as the transition variable implies that large appreciations or depreciations force real exchange rates to adjust towards zero equilibrium level due to arbitrageurs engaging in profitable trading strategies. If the past appreciations or depreciations are small, however, the real exchange rate does not follow a mean reverting behaviour as the arbitrage is not large enough to cover transaction costs.

To test the null of a unit root against a globally stationary ESTAR process, the null and alternative hypotheses are set as $H_0 : \rho = 0$ and $H_1 : \rho < 0$. Obviously, as in Kapetanios et al. (2003), the test suffers from a nuisance parameter problem since the slope parameter, γ, is unidentified under the unit root null hypothesis. Kılıç (2011) overcomes this problem by using the lowest test statistic on $\rho = 0$, t_{ESTAR}, obtained by searching over a fixed parameter space of γ values that are normalized by the sample standard deviation of the transition variable $\Delta\tilde{q}_{t-1}$. That is

$$t_{ESTAR} = \inf_{\gamma \in \Gamma_T} \hat{t}_{\rho=0}(\gamma) = \inf_{\gamma \in \Gamma_T} \frac{\hat{\rho}(\gamma)}{s.e.(\hat{\rho}(\gamma))}$$

where $\Gamma_T = [\underline{\gamma}_T, \overline{\gamma}_T] = \left[\frac{1}{100 s_{\Delta\tilde{q}_{t-1}T}}, \frac{100}{s_{\Delta\tilde{q}_{t-1}T}}\right]$, $s_{\Delta\tilde{q}_{t-1}T}$ is the sample standard deviation of $\Delta\tilde{q}_{t-1}$, $\hat{\rho}(\gamma)$ and $s.e.(\hat{\rho}(\gamma))$ are OLS estimators obtained from the model (6). Over the defined space, t_{ESTAR} is obtained using the grid size of $\frac{1}{100 s_{\Delta\tilde{q}_{t-1}T}}$. The asymptotic critical values of the t_{ESTAR} statistic, which has a non-standard asymptotic distribution, are tabulated through stochastic simulations.

3. Data and empirical results

Our empirical analysis consists of four bilateral real exchange rates derived from nominal exchange rates of Euro (EUR), Chinese Renminbi (RMD), Russian Ruble (RUB), and the U.S. Dollar (USD) against Turkish Lira (TL). The four currencies chosen represent the top four trading partners of Turkey. According to Turkish Statistical Institute, the European Union (EU), China, Russia and the U.S. are the top four trading partners of Turkey with the gross trading volumes being approximately 40%, 8%, 7% and 5%, respectively, by

[2] See Abadir and Distaso (2007) and Kruse (2011) for further details of the testing procedure.

the end of 2015. In all cases, the real exchange rate is calculated by using the wholesale price index (WPI). In fact, the choice of the price index for testing PPP is somewhat controversial in the empirical literature. While some researchers prefer to use a broad index such as the consumer price index, others favour a narrower index with heavier weight on tradable products, such as the wholesale price index. Given that PPP is expected to hold across tradable goods since no arbitrage opportunities can arise for non-tradable products, we prefer to use the WPI in our analysis. Monthly series covering the period 2001(3)-2015(10) are taken from the International Monetary Fund's *International Financial Statistics* and Federal Reserve data bases. All real exchange rates are converted into natural logarithms and plotted in Fig. 1.

Similar to other emerging market economies, Turkey has a history of high inflation, currency crises, and financial dollarization. Since 1980 Turkish authorities have been using exchange rate in order to stabilize the economy, break the inflation inertia, gain credibility or cope with serious speculative attacks. In this sense, different exchange rate policies have been pursued (see Kasman and Ayhan (2012) and Gormez and Yilmaz (2007) for an excellent chronological review for the history of exchange rate policies). Briefly, with the collapse of the fixed exchange rate regime in 1980, the crawling band regime was implemented for the period 1980–1981 and it was followed by the managed floating regime (1981–1999) and the crawling peg regime (1999–2001). Finally, the crawling policy was abandoned and a floating exchange rate regime was adopted on February 2001 in the aftermath of the one of the most destructive financial crisis in Turkey. To circumvent any possible distortion in the PPP analysis due to these policy changes, we start our sample from March 2001 and investigate the validity of PPP over the period of floating exchange rate regime.

Our empirical investigation starts with application of the conventional unit root tests. We initially employ two popular standard unit root tests, ADF and PP and report the results in the first two columns of Table 1. The results of the ADF and PP tests provide evidence of PPP only in two cases, *TL/USD* and *TL/EURO*. Next, we adopt the Ng and Perron (2001) unit root tests, which are modified

Table 1
Standard linear unit root tests results.

	ADF	PP	MZ_{α}^{GLS}	MZ_{t}^{GLS}	MSB^{GLS}	MP_{T}^{GLS}
TL/USD	-3.128^{**}	-3.059^{**}	−0.459	−0.402	0.874	39.518
TL/YUAN	−2.069	−2.122	−1.123	−0.744	0.663	21.626
TL/EURO	-4.564^{***}	-3.598^{**}	−0.691	−0.461	0.667	24.476
TL/RUBLE	−1.781	−2.185	−4.664	−1.492	0.320	5.331
Critical Values						
1%	−3.47	−3.47	−13.80	−2.58	0.17	1.78
5%	−2.87	−2.87	−8.10	−1.98	0.23	3.17
10%	−2.57	−2.57	−5.70	−1.62	0.28	4.45

Notes: The lag order for ADF and Ng and Perron (2001) unit root tests are chosen using the modified AIC (MAIC) as suggested by Ng and Perron (2001). The bandwidth for the PP test is determined using the Newey-West automatic bandwidth selection procedure for a Bartlett kernel. *, **, *** denote rejection of the null hypothesis of a unit root at 10 percent, 5 percent and 1 percent significance levels.

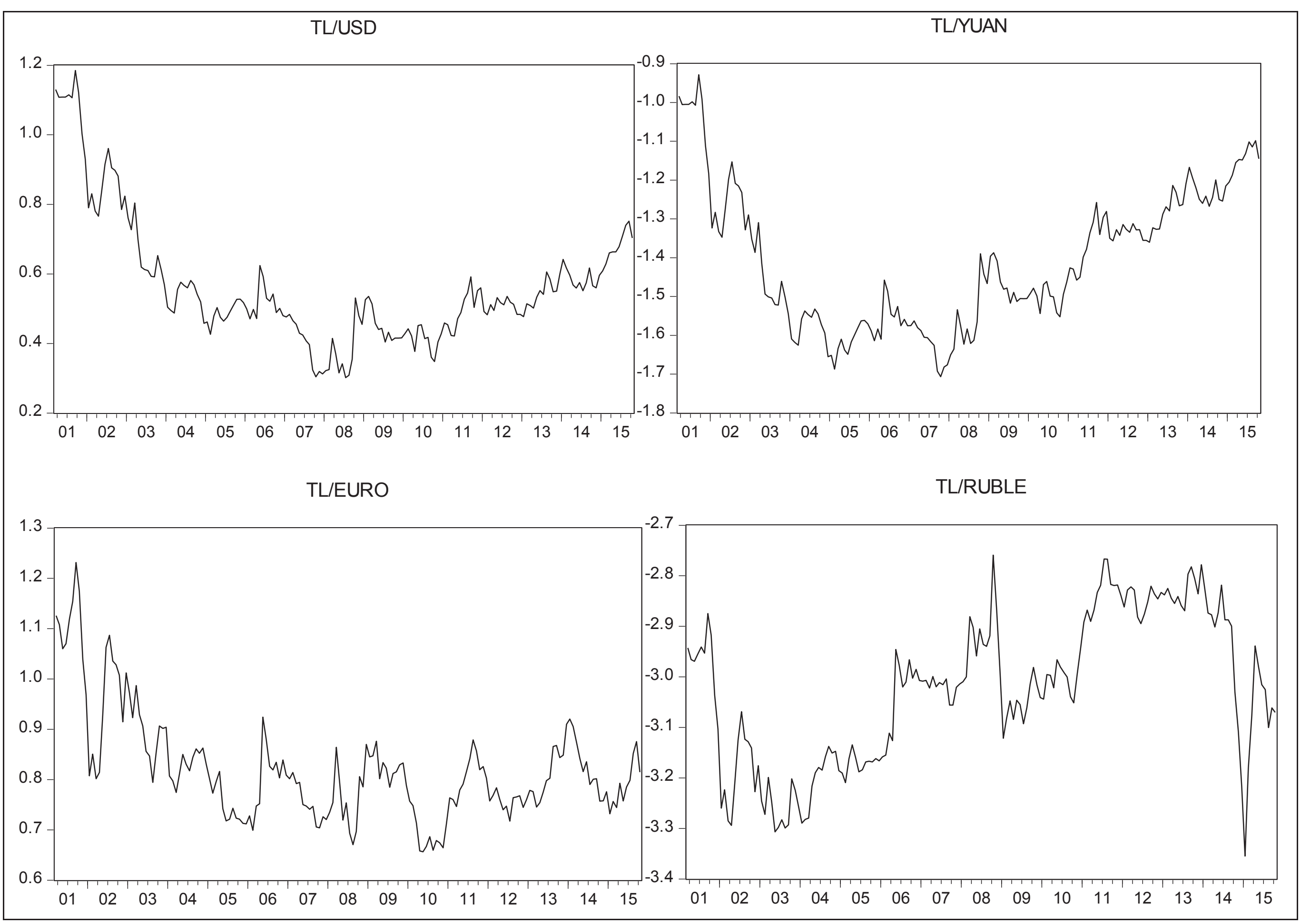

Fig. 1. Real exchange rates.

versions of the standard unit root tests with better performance in terms of power and size distortions.[3] These modified tests, however, provide even less evidence for stationarity of real exchange rates compared to their traditional counterparts and fail to reject the null of a unit root in all cases. As these tests implicitly assume linearity and have low power to detect potential nonlinear stationarity, the conclusions drawn from these tests might be misleading. To propose more reliable results, we proceed with the nonlinear unit root tests.

Before continuing with nonlinear unit root tests, it is noteworthy to mention that the previous tests loose power and deliver misleading results not only when the series follow nonlinear structures but also when the series are confronted with structural breaks. To account for the power loss in the presence of structural breaks, we employ Zivot and Andrews (1992) and Lumsdaine and Papell (1997) unit root tests, which allow for one and two endogenous structural breaks in intercept and/or trend terms, respectively. To be more specific, Zivot and Andrews (1992) propose three different models to test the null hypothesis of a unit root in the presence of structural breaks. Model A allows for a structural break in the intercept, model B allows for a structural break in the trend, and finally model C combines the first two models and allow for a change in both the intercept and the trend. Lumsdaine and Papell (1997), on the other hand, extends the models proposed by Zivot and Andrews (1992) to allow for the possibility of two endogenous structural breaks. Although there is no consensus has emerged so far regarding on which model is superior, Perron (1989) suggests that most macroeconomic time series could be sufficiently modelled by using model A or model C. Following Perron (1989), we employ model A and model C together in our empirical analysis and report the results in Table 2. It appears from the results that the null of a unit root can be rejected only for one case, *TL/EURO*.

Table 2
Structural break unit root tests results.

Zivot and Andrews (1992) Unit Root Test				
	Model A		Model C	
	t	*TB*	*t*	*TB*
TL/USD	−4.18	2006(5)	−4.09	2010(10)
TL/YUAN	−4.51	2010(10)	−4.78	2004(10)
TL/EURO	−5.01**	2003(10)	−5.79***	2003(12)
TL/RUBLE	−4.14	2006(4)	−4.67	2010(10)
Lumsdaine and Papell (1997) Unit Root Test				
	Model A		Model C	
	t	*TB*	*t*	*TB*
TL/USD	−4.36	2006(11), 2008(7)	−6.40	2003(1), 2007(6)
TL/YUAN	−4.73	2008(7), 2010(1)	−6.24	2003(1), 2008(7)
TL/EURO	−5.67	2003(5), 2013(4)	−6.47	2005(4), 2010(2)
TL/RUBLE	−5.10	2006(4), 2010(1)	−5.52	2004(3), 2013(7)

Notes: *t* indicates the t-statistic and *TB* denotes the structural break dates. In both tests, the augmentation order is chosen according to the general to specific approach with a maximum autoregressive order of 12 as suggested by Zivot and Andrews (1992) and Lumsdaine and Papell (1997). Critical values for Model A are given at the 1%, 5% and 10% significance levels as −5.34, −4.80 and −4.58 for the the Zivot and Andrews one-break unit root test and −6.49, −6.24 and −5.96 for the two-break Lumsdaine and Papell unit root test. Critical values for Model C are given at the 1%, 5% and 10% significance levels as −5.57, −5.08 and −4.82 for the the Zivot and Andrews one-break unit root test and −7.34, −6.82 and −6.49 for the two-break Lumsdaine and Papell unit root test. *, **, *** denote rejection of the null hypothesis of a unit root at 10 percent, 5 percent and 1 percent significance levels.

[3] See Ng and Perron (2001) for further details.

Compared to the results obtained from the standard linear unit root tests, it seems that allowing for structural breaks does not provide further evidence for stationarity of real exchange rates.

Next, we proceed with nonlinear unit root tests and report the results in Table 3. The first two columns of Table 3 present the t_{NL} statistic of Kapetanios et al. (2003) obtained from the test regression (3) and τ statistic of Kruse (2011) calculated from the regression (5). It is seen that both tests fail to support stationarity inferences of the standard ADF and PP tests for *TL/USD* and *TL/EURO* and reject the null of a unit root only for one case, *TL/RUBLE*. Next, the t_{ESTAR} statistic of Kılıç (2011) is derived from the test regression (6) and reported in the third column of Table 3. It appears that, while the unit root tests of Kapetanios et al. (2003) and Kruse (2011) provide a similarly small extent of stationarity evidence, the test of Kılıç (2011) rejects the null of a unit root in all cases under consideration. Moreover, the evidences are so strong that all real exchange rates except *TL/EURO* appear to be stationary at 1 percent significance level. For the case of *TL/EURO*, stationarity is ensured at 5 percent significance level, as in the standard ADF and PP tests.

It emerges from these findings that the empirical support for stationarity of real exchange rates and, hence, PPP increases when nonlinearities in real exchange rates are correctly specified. Note that the strongest evidence for real exchange rate stationarity is obtained through the unit root test of Kılıç (2011), which allows for nonlinearity driven by the size of real exchange rate appreciation or depreciation. In this sense, the poor evidence yielded by the test of Kapetanios et al. (2003) and Kruse (2011) might be due to, associating nonlinearity with the size of deviations from PPP and, thus, failing to capture the correct form of real exchange rate nonlinearity.

To illustrate nonlinearity of the real exchange rates, we further plot the estimated transition functions from (6). They are estimated by using constrained MLE library in GAUSS, with the transition parameter γ being standardized by the standard error of the transition variable $\Delta\tilde{q}_{t-1}$ As seen in Fig. 2, the transition functions for the cases of TL*/USD, TL/YUAN* and *TL/RUBLE* are symmetrically *U*-shaped around zero level, as expected under a classical ESTAR model. In all these three cases, there seems to be roughly equal number of observations above and below the zero equilibrium level. Moreover, it is seen that those real exchange rates visit both extreme regimes during the sample period and for each case, the rate of mean reversion of the real exchange rate is the same regardless of whether there is a depreciation or an equal amount of appreciation in the real exchange rate.

Regarding the case of *TL/EURO*, however, the ESTAR type nonlinearity is not very clear with most of the observations

Table 3
Nonlinear unit root test results.

	t_{NL}	τ	t_{ESTAR}
TL/USD	−2.304	5.798	−4.216***
TL/YUAN	−2.300	5.852	−3.582***
TL/EURO	−2.369	5.928	−2.857**
TL/RUBLE	−3.366**	11.380**	−4.404***
Critical Values			
1%	−3.48	13.75	−2.98
5%	−2.93	10.17	−2.37
10%	−2.66	8.60	−2.05

Notes: t_{NL}, $t_{\sup}$ denote, respectively, the t-statistics of the unit root tests of Kapetanios et al. (2003) and Kılıç (2011), while τ is the modified Wald statistic of Kruse (2011). For all tests augmentation orders are selected by using the modified AIC (MAIC) under the null hypothesis, as suggested by Kapetanios et al. (2003) and Kılıç (2011). *, **, *** denote rejection of the null hypothesis of a unit root at 10 percent, 5 percent and 1 percent significance levels.

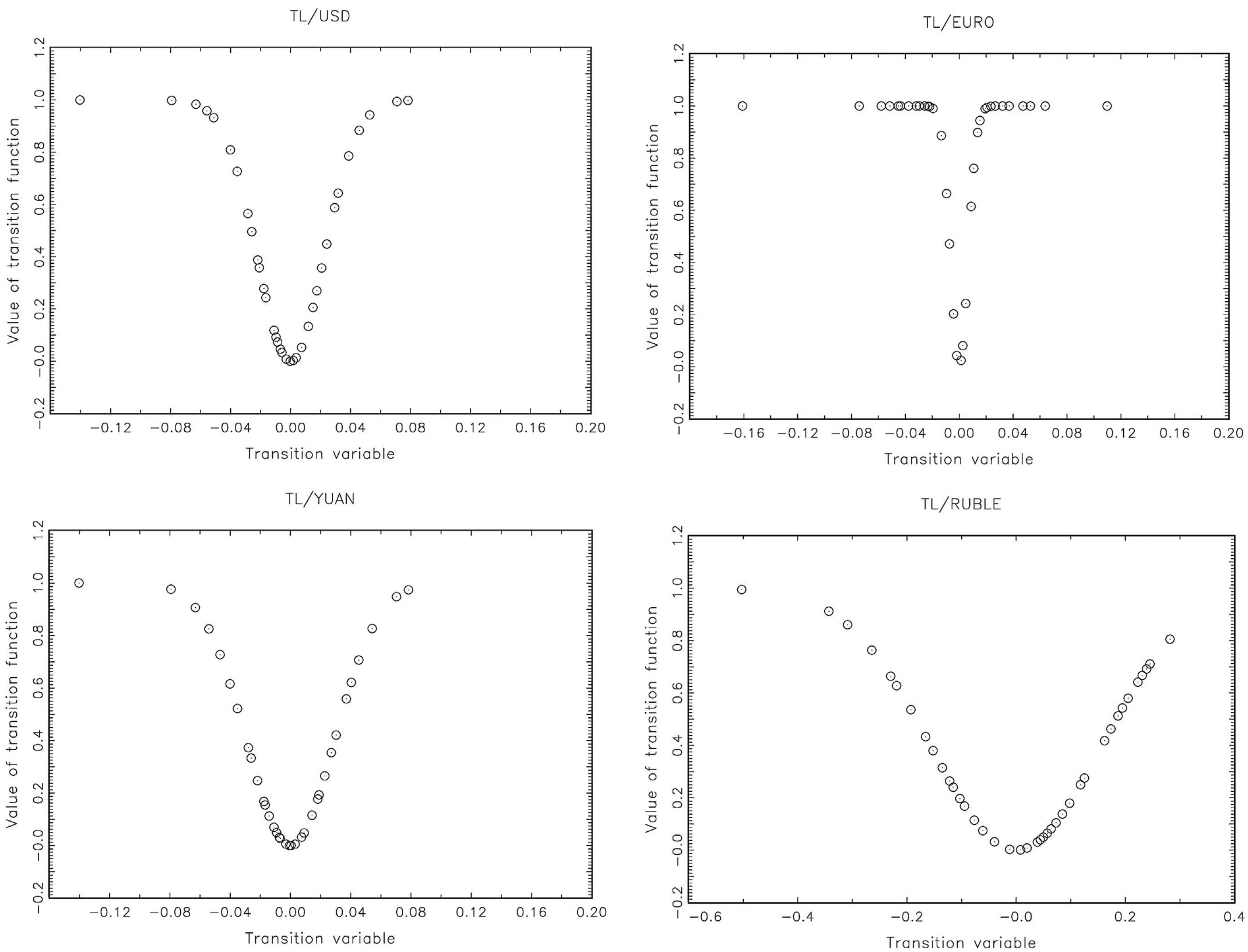

Fig. 2. Scatter plots of estimated transition functions.

clustering in one extreme regime, where the real exchange rate follows a stationary behaviour. Moreover, when the LM-type linearity test of Lukkonen et al. (1988) is applied to establish the presence of nonlinearities in stationary real exchange rates, we observe strong evidence for nonlinearity in *TL/USD*, *TL/YUAN* and *TL/RUBLE*.[4] Nonlinearity in *TL/EURO*, however, appears to be significant only at 10 percent significance level, which suggests linear stationarity of *TL/EURO*. The linear structure of *TL/EURO* clearly explains why, compared to the conventional ADF and PP tests, the test of Kılıç (2011) provides stronger empirical support for stationarity of all real exchange rates, except *TL/EURO*.

Although PPP hypothesis appears to be valid for all real exchange rates under consideration, it is interesting to find that the real exchange rate *TL/EURO* follows a linear stationary pattern while all other real exchange rates exhibit nonlinear behaviour. To clarify this difference one needs to recall that transaction costs and trade barriers are the plausible sources of nonlinearity in real exchange rates. Turkey is a founding member of the World Trade Organization and formed a customs union with the European Union in 1996. With the custom union agreement, Turkey's custom duties, quantitative restrictions on trade with the EU were eliminated and a common external tariff was adopted. Following the implementation of the agreement, Turkey's trade with the EU countries has reached about 40% of its overall trade volume by the end of 2015 and Turkey became the fifth largest trade partner of the EU. On the other hand, Turkey has no preferential trade agreements with China, Russia and the USA, though the initiatives have been launched to start negotiations with the USA. Thereby, it is possible to conclude from our empirical results that the trade between the countries having free trade agreements is less subject to trade barriers and transaction costs and therefore their real exchange rates are more likely to behave as linear stationary processes. This result is in line with that of Kutan and Zhou (2015) who find that the real exchange rates of highly integrated economies exhibit linear stationarity due to low transaction costs and barriers in their international trade, implying that transaction costs and trade barriers are truly important sources of nonlinearity in real exchange rates.

4. Conclusion

This paper proposes an analysis for the empirical validity of the

[4] Results from the LM-type linearity test are not presented here but available upon request.

PPP hypothesis between Turkey and its four major trading partners, the European Union, Russia, China and the US over the floating exchange rate period, 2001(3)-2015(10). Although enormous literature is available on testing the empirical validity of the long-run PPP, no consensus has emerged due to the conflicting evidences. Over recent years, it has been argued that the puzzling results of PPP may be due to the potential nonlinear nature of real exchange rates which is ignored by the standard approaches. Accordingly, some recent studies utilizing nonlinear econometric methods have provided fairly convincing evidence for the empirical validity of the PPP hypothesis.

With the motivation of these recent studies, we reinvestigate the PPP hypothesis by adopting popular conventional unit root tests along with a battery of newly developed nonlinear approaches. Overall, our empirical discussion suggests that the empirical evidence in favour of PPP increases when nonlinearities are properly accommodated. In this sense, despite its growing popularity in the PPP literature, it is observed that the nonlinear unit root test of Kapetanios et al. (2003) provides no further evidence for stationarity of real exchange rates compared to the standard unit root tests. A similar result is produced by the unit root test of Kruse (2011). The unit root test of Kılıç (2011), on the other hand, appears to be decisive in uncovering evidence for PPP by associating nonlinearity with the size of real exchange rate appreciation or depreciation rather than the size of deviations from PPP as in Kapetanios et al. (2003) and Kruse (2011). With the use of the test of Kılıç (2011), we obtain highly strong evidence in favour of PPP for all real exchange rates under consideration. This implies that PPP can be used to determine the equilibrium exchange rates and making unbounded gains from arbitrage in traded goods is not possible in all cases we examine. Our results further reveal that the real exchange rates of the countries which have the free trade agreement follow a linear path, pointing transaction costs and trade barriers being important sources of real exchange rate nonlinearities.

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