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Nonlinear Adjustment to Purchasing Power Parity: An Empirical Evidence for Emerging and Developed Countries

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In this study, we fit nonlinearity mean-reverting processes to real exchange rate behaviour for 23 emerging and developed countries over the period (1973-2005) consistent with the hypothesis of transaction costs in international arbitrage. Our empirical work shows that deviations from PPP can be governed by exponential or logistic smooth transition autoregressive models. The estimated transition functions reveal a higher adjustment speed in developed countries. Also the estimated generalized impulse response functions show that real exchange rate response to chocks is depending upon sign and size of the innovations. The ESTAR/LSTAR processes exhibit a better predictive capacity than linear process.

Field of Research: International Finance, Developed and emerging economies

1. Introduction

The theory of purchasing power parity (PPP) has been a central issue in economics for many years. PPP relationship suggests that a common basket of tradable goods, when quoted in the same currency, costs the same in all countries when transportation costs and tariffs are disregarded. The parity condition is based on extremely restrictive hypothesis: perfect inter-country commodity arbitrage, no transaction costs, taxations, subsidies, any other trade restrictions, and the same composition of the market baskets and price indices across countries. Major of empirical studies show that PPP may be valid only for long-run horizon. The monumental contribution of Engle-Granger, 1987; cointegration technique has brought a new way of testing PPP as a long-run equilibrium relationship between domestic and foreign prices and the nominal exchange rate.

Large empirical studies are given in the literature relative to PPP validity (see, for example, Corbae & Ouliaris 1988; Mark 1990; Cheung & Lai, 1993; Lothian & Taylor, 1996; Lothian &Taylor, 2000; O'Connell, 1998; Engel, 2000; Sercu , Uppal & Van Hulle , 1995; Enders & Dibooglu, 2001, Kargbo, 2003; Enders & Chumrusphonlert, 2004; Narayan, 2007, etc.).

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Empirical approaches based on time series or panel data have shown contradictory results and have given an impulsion to the theoretical analysis of the “PPP problem”. For these considerations, the recent empirical studies have been focused on the weak power of standard unit root tests and inclusion of the transaction costs in international trade. In fact, one potential solution to “PPP problem” relies on low power of the statistical tests used. More precisely, the standard unit root test power depends upon the length of the sample period. In this context, some researchers as, Cheung and Lai, 1993; and Lothian and Taylor, 1996; have been able to detect mean reverting process in real exchange rate (RER) behaviour. In order to avoid the weak power of unit root test, some other authors have used panel unit root tests to RER series (O’Connell, 1998). Concerning the presence of transactions costs in international arbitrage, Benninga and Protopapadakis, 1988; Dumas, 1992; were the first to examine their implications on the RER behaviour. According to these authors, deviations from the PPP are not mean-reverting as long as they are small (compared to the transaction costs). If the deviations become large enough (as a consequence of an exogenous shock), long-run PPP equilibrium is reached very quickly. The speed of adjustment towards PPP may depend on the size of the deviation from it. The dynamic process of the RER then is nonlinear. In fact, transaction costs create an inaction band for the RER within which the marginal costs of arbitrage exceed the marginal benefit. Under the hypothesis of instantaneous goods arbitrage at the borders of the inaction band we can assimilate barriers to thresholds. Given these considerations, some authors as Obstfeld and Rogoff, 2000; have suggested that Dumas’s model can give some highlights to the “PPP problem” but it is unable to explain the RER behaviour inside the “inaction band”. On other hand, the model of Dumas has given important empirical implications relative to the nonlinearity of deviations from PPP. This hypothesis has been initially exploited by Micheal, Nobay & Peel, 1997; with a smooth transition autoregressive (STAR) representation of the deviation from the parity.

Our study complements these papers by extending the empirical investigation to a sample of emerging and developed countries. So, our contribution is on the empirical front. We attempt to describe RER adjustment toward long-run PPP relationship consistent with the hypothesis of transaction costs in international arbitrage. We test nonlinearity mean-reverting hypothesis using STAR framework. We attempt to add some fresh empirical evidence and to give highlights to the following points: (1) given that STAR-type nonlinearity is present in the RER, we should identify LSTAR or ESTAR is better to fit our data; (2) this allows us to give additional evidence on symmetry or asymmetry of RER adjustment toward PPP; (3) and to see whether the speed of adjustment towards PPP depends on the sign and the magnitude of the deviation from it. The empirical investigation is conducted on 23 emerging and developed countries covering, in quarterly data, the sample period (1973-2005). It can be considered as an extension of some empirical studies as Baum, Barkoulas & Caglayan, 2001; Sarno, Taylor & Peel, 2001; Liew, Chong & Lim, 2003; and Kapetanios, Shin & Snell, 2003 a, b. Our work can be distinguished from previous studies on the following points: (1) the sample covers conjointly developed and emerging countries; (2) it considers the lunch of the euro on January 1999; (3) in addition to standard unit root tests, the

Kiatkowski, Phillips, Shmidt & Shin, 1992; (KPSS) stationarity test is employed in this study; (4) we have also used some recent nonlinear cointegration tests: Kapetanios, Shin & Snell, 2003 a, b,(KSS) and Eklund, 2003 a, b; (5) generalized impulse response functions for the estimated STAR models are used to examine the dynamic response of deviations from PPP to innovations, which highlights the importance of nonlinear modelling.

The rest of the paper is structured as follows: in the next section, we expose a brief review of the previous empirical studies of the PPP. In section 3, we discuss the class of nonlinear processes and their implications on RER behaviour. Section 4 presents methodology and the empirical design. In section 5, we report the empirical results of linear and nonlinear models estimations for dynamic adjustment of deviations from PPP. A final section summarizes and concludes our study.

2. Literature Review

This section provides a brief review of the available results, and relates our work to the existing literature relative to RER. As suggested by Dumas, 1992; and Sercu, Uppal & Van Hulle, 1995; the presence of transaction costs in international trade implies that deviations from PPP have nonlinear convergence. Transaction costs create a “band of inaction” within which international price differentials are not arbitrated away; only price differentials exceeding transaction costs (i.e. “outside the band”) are profitable for arbitrage. More precisely, Duma, 1992; suggested that within the transaction band, when no trade takes place, the process is divergent so that the exchange rate spends most of the time away from parity. This implies that PPP’s deviations last for a very long time, although they certainly do not follow a random walk process (Dumas, 1992; p. 154). In an initial empirical investigation, Micheal, Nobay & Peel, 1997; have applied an exponential smooth transition autoregressive model to two data sets covering the periods (1921-1925; 1800-1992) for G4 countries. They concluded that RER behaviour is governed by a nonlinear process (Micheal, Nobay & Peel, 1997; p. 877). Using consumer and whole price indices for a sample covering 17 developed countries over the period (1973-1995), Baum, Barkoulas & Caglayan, 2001; have reported additional evidence supporting the ESTAR process. The estimated generalized impulse response functions show that adjustments of deviations from PPP are nonlinear and induced by the presence of transaction costs. These results are partially similar to O’Connell (1998) conclusions. In another work, Sarno, Taylor & Peel, 2001; have attested the validity of the ESTAR model. Their empirical study has been conducted on panel and time series databases covering G-7 countries for the period (1973-1999). The half-life and the generalized impulse response functions show that RER adjustments are functions of chocks and initial conditions (Sarno, Taylor & Peel, 2001; p. 1037). Using a large sample covering the same period, Sollis, 2003; has found evidence supporting the ESTAR process. We should note that other empirical evidences of the effect of transaction costs on tests of PPP, based on a standard threshold autoregressive (TAR) model (Tong, 1990) are provided by Obstfeld & Taylor, 1997. Coakley & Freuters, 2001;Sarno, Taylor & Chowdhury, 2004; and Holmes &Wang ,2004. The TAR model allows for a transaction costs band within which no-adjustment takes place (i.e. deviations from PPP may be governed by unit root behaviour), while outside of the band, the process switches abruptly to become stationary autoregressive. Sarno, Taylor & Chowdhury, 2004; found empirical evidence in favour of TAR models. However, this process has not been supported by Coakley & Freuters, 2001.

The co-authors have conducted their empirical investigation on 11 European countries for the period (1973-1997). A similar conclusion was obtained by Holmes & Wang, 2004. Their study was focused on the context of some African countries (1973-1997). To model the behaviour of the RER in a nonlinear context, Dufrénot, Mathieu, Mignon & Péguin-Feissolle, 2002; have employed conjointly the STAR and ARFIMA processes. The idea was to take into consideration the long range dependencies and nonlinearities in the dynamic behaviour of the deviations from PPP. The obtained results show the pertinence of this framework. In a more recent paper, Dufrénot, Lardic, Mathieu, Mignon & Péguin-Feissolle, 2004; have approved the validity of this framework for the German context (1979-1999). The hypothesis of the long-range dependence in the dynamic of the RER has been tested by Cheung & Lai, 2000. They found evidence of PPP mean-reversion, through 94 countries (1973-1994), using fractional cointegration approach. For emerging countries, comprehensive evidence on the validity of PPP in a nonlinear context is scant. To our knowledge, the most recent inclusive evidence comes from Alba and Park, 2003; Alba & Papell, 2006; and Bahmani-Oskooee, Kutan & Zhou,2006. Using the standard tests of stationary of the RER for 11 Middle East countries, Bahmani-Oskooee, 1998; the stationary hypothesis has been supported for only three countries. The same sample has been employed by Sarno (2000). The author found empirical evidence in favour of STAR and STRECM process. In a more recent paper, Bahmani-Oskooee, Kutan & Zhou, 2006; have employed real effective exchange rate data from 88 developed countries for the period (1980-2005). They attested that nonlinear adjustment towards PPP in developed countries is an important phenomenon. More importantly, they suggested that country characterizes indicate that PPP holds more often for high-inflation countries and for countries with high flexibility in their exchange rates.

In their paper, Liew, Chong & Lim, 2003; have focused their attention on Malaysian context. Based on consumer price and whole price indices (respectively, CPI and WPI) and RER quarterly time series covering the period (1973-1997), the empirical evidence confirmed the validity of ESTAR process. Moreover, the out-of-sample forecasting performance analysis shows that ESTAR process exhibits better predictions than linear and LSTAR models (Liew, Chong & Lim, 2003;p. 59).

3. Nonlinear Adjustment and ESTAR/LSTAR Process

The real exchange rate, where the transaction costs are ignored, is obtained from the absolute PPP hypothesis:

$$s_t - p_t^* + p_t = c + d_t \qquad (1)$$

Where s_t is the logarithm of the nominal exchange rate; p_t^* and p_t are the logarithms of the domestic and foreign price levels, respectively; c is a constant; and d_t is a disturbance term capturing deviations from PPP. The stationary of the RER may be interpreted as the validity of the PPP in the long run.

The strict version of the absolute PPP can be tested by estimating the following regression:

$$s_t = c + \beta^* p_t^* + \beta p_t + d_t \qquad (2)$$

by imposing the joint hypothesis of symmetry and proportionality $\beta^* = -\beta = 1$. The validity of the PPP theory as long-run equilibrium concept necessitates the presence of cointegration relationship in the system (s_t, p_t, p_t^*). Engle & Granger, 1987; and Johansen, 1988; tests may be used in this regard. In the context of the linear cointegration methodology, the speed of adjustment to restore equilibrium is independent of the magnitude of disequilibrium (Baum, Barkoulas & Caglayan, 2001; p. 6). As noted above, the presence of transaction costs imply a nonlinear process. Dumas (1992), Sercu, Uppal & Van Hulle, 1995; and Micheal, Nobay & Peel, 1997; show that adjustment of real exchange rates toward PPP is necessarily a nonlinear process. Obstfeld & Taylor, 1997; have investigated the nonlinear nature of adjustment process in terms of a threshold autoregressive models (TAR) (Tong, 1990). An alternative characterisation of nonlinear adjustment, which allows for smooth rather than discrete adjustment, is in terms of a smooth threshold autoregressive (STAR) model. In the STAR framework, the smooth adjustment leads to the smooth function. In this paper, we apply STAR methodology to analyse the dynamic behaviour of deviations from PPP. Following Dufrénot, Lardic, Mathieu, Mignon & Péguin-Feissolle, 2004; Liew, Chong & Lim, 2003; Micheal, Nobay & Peel, 1997; Baum, Barkoulas & Caglayan, 2001; we use STAR models in order to specify PPP's deviations. Formally, the STAR process can be written as follows:

$$d_t = k + \sum_{j=1}^{p} \pi_j d_{t-j} + \left(k^* + \sum_{j=1}^{p} \pi_j^* d_{t-j} \right) \times F(d_{t-r}, \gamma, c) + u_t \qquad (3)$$

Where $\{d_t\}$ is a stationary and ergodic process, $u_t \to iid(0,\sigma^2)$, $\gamma \succ 0$ is the transition speed, d_{t-r} is the transition variable and c is the location parameter. The regular exponential autoregressive (EAR) is a special case of equation (3) with $k^* = c^* = 0$. (See, for example, Haggen & Ozaki, 1981; and Priersteley, 1988; p. 83-98). We should distinguish between logistic and exponential transition functions. For ESTAR process, the transition function can be expressed as follows:

$$F(d_{t-r},\gamma,c) = 1 - exp\left[-\gamma\left(d_{t-r} - c^*\right)^2\right] \quad (4)$$

When $d_{t-r} = c^*$, its equilibrium value, $F(.) = 0$ and the model becomes a standard linear $AR(p)$ specification. According to Michael et al. (1997), the ESTAR model may be considered as a generalisation of a particular form of the two-threshold TAR model (Micheal, Nobay & Peel, 1997; p. 866). The logistic STAR model (LSTAR) is a usual alternative case of the ESTAR models, where the transaction function can be represented as:

$$F(d_{t-r},\gamma,c) = \frac{1}{1 + exp\left[-\gamma\left(d_{t-r} - c^*\right)\right]} \quad (5)$$

The LSTAR family contains as a special case the single-threshold TAR model with asymmetric adjustment to positive/negative deviations. For our purposes, we consider the LSTAR model as plausible for modelling the PPP deviations.

Following Sarno, Taylor & Peel, 2001; Micheal, Nobay & Peel, 1997; Baum, Barkoulas & Caglayan, 2001; we use a reparameterized form of the STAR model in equation (3), as given by:

$$y_t = k + \lambda d_{t-1} + \sum_{j=1}^{p-1}\phi_j y_{t-j} + \left(k^* + \lambda^* d_{t-1} + \sum_{j=1}^{p-1}\phi_j^* y_{t-j}\right) \times F\left(y_{t-r},\gamma,c\right) + u_t \quad (6)$$

With $y_t = \Delta d_t$

In this specification, λ and λ^* are the crucial parameters. Under the hypothesis of transaction costs, the large deviations from PPP, the stronger are the tendency to move back to equilibrium. This implies that quantity $\lambda + \lambda^*$ and λ^* must be negative to ensure global stability and mean reversion in outer regime. However, for small deviations from PPP, y_t may follow a unit root or explosive behaviour (i.e. $\lambda \succ 0$), as long as it does not exceed λ^* in absolute value. This analysis presents major implications for conventional cointegration test of PPP which is based on a linear AR(p) process. This process can be expressed as a standard augmented Dickey-Fuller (ADF) regression:

$$y_t = k' + \lambda' d_{t-1} + \sum_{j=1}^{p-1}\phi_j' y_{t-j} + v_t \quad (7)$$

If equation (6) is the correct specification, then the estimated parameter λ' in the ADF regression, should be estimated as some combination of λ and λ^*. Hence, the null hypothesis $H_0 : \lambda' = 0$ (i.e. no linear cointegration) may not be rejected against the stationary linear alternative hypothesis $H_1 : \lambda' \prec 0$, even though the true nonlinear process is globally stable with $\left(\lambda + \lambda^*\right) \prec 0$. Thus failure to reject the unit root hypothesis on the basic of the linear model does not necessarily invalidate long-run PPP. Consequently, the failure to valid cointegration on the basis of the linear model does not necessarily reject the long-run PPP. The next section exposes methodology. We present a brief description of Luukkonen, Saikkonen & Teräsvirta, 1988; (LST) linearity test. This test procedure will be employed in order to determinate the delay parameter of the nonlinear model. A short sequence of (F) tests will be used to choose between ESTAR and LSTAR family of models.

4. Methodology and Research Design

We apply the LM-type linearity test developed by Teräsvirta, 1994; based on the estimating by OLS the artificial regression:

$$y_t = \phi_0 + \sum_{i=1}^{p}\left(\phi_{1i}y_{t-i} + \phi_{2i}y_{t-i}y_{t-r} + \phi_{3i}y_{t-i}y_{t-r}^2 + \phi_{4i}y_{t-i}y_{t-r}^3\right) \qquad (8)$$

and testing the null hypothesis of linearity $H_{0L} : \phi_{4i} = \phi_{3i} = \phi_{2i} = 0$ ($i = 1...p$) against the general alternative of nonlinearities. The delay parameter (r) is obtained by repeating the linearity test for a set of plausible values of $(r = 1,2,..,12)$ and choosing the value $(\hat{r})$ that minimises the *p-value* of the linearity test. Assuming the linearity is rejected we follow the approach suggested by Teräsvirta, 1994; by testing a sequence of nested hypothesis:

$$H_{01} : \phi_{4i} = 0 \text{ (i=1, 2,.., p)} \qquad (9a)$$

$$H_{02} : \phi_{3i} = 0 \middle| \phi_{4i} = 0 \text{ (i=1, 2,.., p)} \qquad (9b)$$

$$H_{03} : \phi_{2i} = 0 \middle| \phi_{2i} = 0, \phi_{4i} = 0 \text{ (i=1, 2,.., p)} \qquad (9c)$$

The preceding may suggest the following rule decisions: i) if H_{01} is rejected then we propose a LSTAR model; ii) if H_{01} is accepted and H_{02} is rejected then we choose ESTAR model and iii) if H_{01} and H_{02} are accepted and H_{03} is then we select a LSTAR model. After specifying the family of models and detecting the delay parameter, we can proceed to estimate and evaluate the nonlinear model. Equation (6) is estimated by nonlinear lest squares (NLLS). According to Van Dijk, Teräsvirta & Franses, 2000; the NLLS is equivalent to the Quasi-Maximum likelihood method (QMLE) (*The QMLE is obtained by using the CMLMT procedure of GAUSS program).* Evaluation of models includes 1) the properties of the residuals (autocorrelation, normality and heteroscedasticity); 2) the validation tests of Granger & Teräsvirta, 1993; and 3) the misspecification tests of Eithreim &Teräsvirta, 1996.

5. Empirical Investigation

5.1. Data

Our data base comprises quarterly observations on consumer price indices and nominal foreign exchange rates for 14 developed countries: the Canada, France, Germany, UK, Italy, Japan, New-Zealand, Australia, Belgium, Denmark, Norway, Luxembourg, Sweden and Switzerland and 9 emerging countries: India, Indonesia, Korea, Malaysia, Philippines, Singapore, Thailand, Mexico and Paraguay against the US dollar. All series are extracted from the International Monetary Fund's *International Financial Statistics* database and span the period (1973: I- 2005: II). For the euro area countries, the sample period has been subdivided in two sub-samples pre and post euro. The first sub-sample covers the period from 1973:I to 19998:IV and totalling 105 observations. For all the countries, the (log) RER series where normalized on the beginning of the each sub-sample period.

5.2. Linear cointegration tests

As a preliminary exercise we should test for unit root in RER behaviour. As mentioned above, the validity of PPP hypothesis as a long-run equilibrium relation requires the stationary of the deviations from PPP (i.e. $d_t \sim I(0)$ in equation (1)). In order to compare our results with previous empirical studies, we estimate as in Micheal, Nobay & Peel, 1997; the restrictive version of PPP for our quarterly data. We impose the joint restrictions of symmetry and proportionality $\beta^* = -\beta = 1$. Patel, 1990; shows that these restrictions will hold only if the prices are constructed using the same weight. Sercu, Uppal & Van Hulle, 1995; have also suggested that restrictions violations can be explained by the omission of home and foreign money stocks from the PPP regression. We adopt the two-stage cointegration procedure suggested by Engle & Granger, 1987; and the multivariate Johansen, 1988; tests. Micheal, Nobay & Peel, 1997; suggest that non linearity of deviations from PPP does not affect the unit root tests for consumer price index and nominal exchange rate time series or the super-consistency of the OLS estimators of β and β^*. However, the test for cointegration will be affected by the nonlinearity. We tested for unit root behaviour for each of the consumer price index and nominal exchange rates series expressed in level and first difference by using ADF and Phillips-Perron ,1988; (PP) tests. Results are reported in Table 1. From these results, the level time series are not stationary. The bandwidths in the unit root test were allowed to vary cross individual countries so as to mop up any residual serial correlation. The bandwidth was based on Newey-West using Barlett Kernel spectral estimation method. Whether or not a time trend is included in the unit root test estimation, PP and ADF tests show that the first differences of all the time series are stationary. In keeping with the very large number of studies of unit root behaviour for these exchange rates we were in all cases unable to reject the unit root null hypothesis for conventional levels of significance.

Table 1.

Results of unit root tests

Countries	*ADF*				*PP*				*KPSS*			
	P_t	p_t	S_t	s_t	P_t	p_t	S_t	s_t	P_t	p_t	S_t	s_t
Panel a. Developed countries												
Australia	-2.45	-2.81	-2.00	-8.93‡	-2.79	-8.26‡	-1.75	-8.91‡	1.17	0.43	1.14	0.19
Belgium	-1.57	-3.44*	-1.85	-7.28‡	-1.01	-5.59‡	-1.95	-7.40‡	0.91	0.06	0.18	0.06
Belgium€	-1.61	-4.80‡	-0.25	-4.55‡	-1.61	-4.79‡	-0.40	-4.55‡	0.71	0.07	0.45	0.54
Canada	-1.49	-6.71‡	-2.14	-4.08‡	-1.65	-6.85‡	-1.86	-8.59‡	0.36	0.42	0.98	0.21
Denmark	-3.26	-3.90†	-1.98	-8.88‡	-3.01	-11.2‡	-2.03	-9.02‡	0.50	0.71	0.12	0.08
France	-2.24	-2.26	-2.07	-6.82‡	-2.29	-4.97‡	-1.76	-6.82‡	0.69	0.64	0.3	0.09
France€	-1.83	-4.50‡	-0.28	-4.72‡	-1.84	-4.57‡	-0.40	-4.72‡	0.62	0.18	0.44	0.54
Germany	-1.58	-2.00†	-1.72	-7.75‡	-3.46	-4.08‡	-2.01	-7.78‡	1.22	0.58	0.78	0.07
Germany€	-0.14	-4.12‡	-0.28	-4.72‡	-0.14	-4.22‡	-0.40	-4.72‡	0.73	0.08	0.44	0.14
Italy	-3.77	-1.33*	-1.95	-6.92‡	-4.23	-3.60†	-1.93	-7.01‡	0.31	0.08	0.90	0.17
Italy€	-1.95	-5.51‡	-0.10	-1.26‡	-1.99	-5.51‡	-0.31	-4.24‡	0.14	0.18	0.44	0.55
Japan	-0.65	-3.75†	-1.08	-8.62‡	0.82	-8.92‡	-1.18	-8.69‡	1.34	0.34	1.23	0.06
Luxembourg	-1.38	-3.62*	-1.85	-7.28‡	-1.24	-7.53‡	-1.95	-7.40‡	1.07	0.24	0.18	0.06
Luxembourg€	-0.92	-3.79†	-0.08	-1.28*	-1.11	-3.79†	-0.31	-4.16‡	0.43	0.20	0.44	0.55
New-Zealand	-2.36	-3.07	-1.93	-7.40‡	-2.50	-4.61‡	-1.62	-7.48‡	1.08	0.63	1.00	0.12
Norway	-2.13	-3.29*	-1.93	-9.17‡	-1.57	-7.85‡	-1.76	-9.17‡	0.98	0.25	0.69	0.09
Sweden	-1.86	-2.77	-1.72	-8.52‡	-1.74	-8.88‡	-1.61	-8.64‡	1.07	0.53	0.96	0.08
Switzerland	-3.48	-2.89†	-2.06	-8.89‡	-2.28	-7.57‡	-2.33	-8.93‡	1.18	0.34	1.10	0.11
UK	-4.57	-2.23	-2.81	-9.33‡	-5.61	-9.14‡	-2.51	-9.37‡	1.13	0.71	0.56	0.17
Panel b. Emerging countries												
Korea	-5.02	-3.61†	-1.84	-8.16‡	-4.16	-7.41‡	-1.74	-8.16‡	1.25	0.60	1.165	0.134
India	-1.24	-1.23	-0.51	-7.40‡	0.048	-7.30‡	-0.25	-7.52‡	1.29	0.19	1.35	0.25
Indonesia	-0.46	-4.91‡	-0.29	-6.76‡	-0.35	-4.83‡	-0.36	-8.57‡	1.32	0.11	1.32	0.05
Malaysia	-1.50	-4.28‡	-1.06	-7.77‡	-1.42	-7.75‡	-0.57	-7.51‡	1.0	0.20	1.04	0.16
Mexico	-1.73	-1.51	-1.39	-2.95	-1.14	-3.41*	-1.18	-8.50‡	1.34	0.30	1.32	0.27
Paraguay	-0.68	-2.66	0.312	-5.86‡	-0.23	-7.74‡	0.312	-5.86‡	1.38	0.26	1.35	0.23
Philippines	-0.92	-3.89†	-0.55	-6.59‡	-1.30	-5.67‡	-0.42	-6.75‡	1.38	0.13	1.33	0.07
Singapore	-0.12	-5.64‡	-1.71	-10.5‡	-0.39	-6.15‡	-1.71	-10.5‡	1.31	0.07	1.12	0.18
Thailand	-1.79	-7.39	-2.08	-7.39	-0.49	-7.65	-0.68	-7.70	1.05	0.10	1.15	0.08

Notes**:** €: post euro period (1999: I-2005: II). ADF: augmented Dickey- Fuller,1981; test statistic. PP: Philipps & Perron, 1988; test statistic. KPSS: Kiatkowski, Phillips, Schmidt & Shin, 1992; test statistic. P_t and p_t level prices in level and in first difference respectively. S_t and s_t nominal exchange rates prices in level and in first difference respectively.*, † et ‡ denote significant at 10%, 5% and 1% levels respectively.

Equation (2) has been estimated with OLS method. We used the standard Wald test statistics to test the hypothesis of symmetry and proportionality $\beta^* = -\beta = 1$. Table 2 provides the estimations results for respectively developed and emerging countries. It can be seen that the restrictions $\beta^* = -\beta = 1$ is jointly accepted only for Denmark and Germany for the pre-euro period. This result is in line with previous studies (Baum, Barkoulas & Caglayan, 2001).

Table 2.
Estimation results of PPP absolute version

Model : $s_t = c + \beta p_t + \beta^* p_t^* + \varepsilon_t$

Countries	c		β		β^*		Wald
	$\hat{c}$	t.stat	$\hat{\beta}$	t.stat	$\hat{\beta}^*$	t.stat	
Panel a. Developed countries							
Australia	-1.52	-5.46‡	0.58	3.30‡	-0.17	-0.73	154.40
Belgium	2.47	6.81‡	2.00	4.29‡	-1.77	-4.38‡	9.28
Belgium-€	6.49	1.08	2.57	0.36	-3.92	-0.66	10.58
Canada	-0.94	-14.09‡	-0.36	-2.27†	0.63	3.82‡	316.06
Denmark	2.08	11.38‡	1.48	5.10‡	-1.52	-4.78‡	2.82‡
France	2.70	11.80‡	2.35	10.44‡	-2.57	-9.53‡	37.25
France-€	25.73	7.95‡	-16.49	-6.02‡	10.84	5.11‡	65.68
Germany	0.75	0.59	0.76	1.185	-0.81	-2.17†	2.14‡
Germany-€	-18.0	-3.12‡	13.25	4.80‡	-9.27	-5.80‡	34.33
Italy	9.51	10.02‡	1.44	6.00‡	-1.90	-4.27‡	9.74
Italy€	8.12	3.75‡	-7.68	-2.22†	5.97	1.70†	21.30
Japan	7.29	15.76‡	-0.53	-5.23‡	1.10	10.00‡	2880.7
Luxembourg	2.30	3.54‡	-0.94	-2.42‡	1.21	2.32‡	93.75
Luxembourg€	0.89	0.58	-4.74	-8.08‡	4.47	5.51‡	161.7
New-Zealand	-1.73	-4.10‡	0.31	2.47‡	0.19	0.87	30.86
Norway	1.05	5.08‡	0.36	1.80†	-0.16	-0.67	19.97
Sweden	-0.70	-2.20†	-0.19	-0.92	0.78	2.84‡	100.84
Switzerland	2.65	4.07‡	0.06	0.17	-0.55	-2.60‡	19.85
UK	0.21	0.62	-0.79	-4.04‡	0.84	3.147‡	664.3
Panel b. Emerging countries							
Korea	5.46	8.34‡	0.68	3.07‡	-0.38	-1.05	15.74
India	1.04	6.52‡	1.33	33.15‡	-0.82	-11.41‡	1582.6
Indonesia	5.2	11.26‡	1.40	18.95‡	-0.83	-4.76‡	550.73
Malaysia	-2.75	-11.7‡	2.15	11.15‡	-1.31	-8.90‡	741.4
Mexico	-0.12	-0.18	0.97	39.98‡	-0.58	-3.44‡	25.02
Paraguay	10.27	20.38‡	1.46	36.08‡	-1.98	-13.55‡	405.54
Philippines	3.37	7.25‡	1.21	16.39‡	-1.19	-6.86‡	121.10
Singapore	3.38	9.39‡	-0.58	-2.41‡	-0.03	-0.23	97.62
Thailand	2.27	13.36‡	1.92	8.63‡	-1.67	-6.62‡	228.82

Notes: €: post euro period (1999: I-2005: II). t.stat: Student statistic test. Wald : Wald test statistic of the null hypothesis $H_0 : \beta^* = -\beta = 1$.*, † et ‡ denote significant at 10%, 5% and 1% levels respectively.

Table 3 reports estimating results of linear cointegration tests for respectively developed and emerging countries. Thus, the PPP relationship in equation (2) is estimated using the two-steps Engle & Granger, 1987; procedure and the multivariate Johansen, 1988; approach. Concerning the first cointegration procedure, we employ Phillips & Perron (1988) (PP), ADF and Kiatkowski, Phillips, Schmidt & Shin, 1992; (KPSS) tests in order to detect the presence of

unit root in all residuals terms. The lag length of the residual process for each country is specified using Akaike and Schwarz information criteria allowing for a maximum lag length of 4. Our results show that the null hypothesis of unit root can not be rejected by ADF and PP tests. However, this result is in contradiction with KPSS test results. In fact, the KPSS test supports the hypothesis of stationarity of residual terms (i.e. linear cointegration). Our results are consistent with Dufrénot, Lardic, Mathieu, Mignon & Péguin-Feissolle, 2004. These authors have accepted the null hypothesis of linear cointegration for a sample of 14 European countries covering the period (1979: I-1999: II) (Dufrénot, Lardic, Mathieu, Mignon & Péguin-Feissolle, 2004; p. 4).
For the Johansen method, we have employed VAR frame work which incorporates of the short-and-long run dynamics of the variable system. We should note that the lag length of the VAR process for each country is determined employing the multivariate information criteria that allows for a maximum lag length of 12.

Table 3.
Linear cointegration results for the PPP hypothesis

countries	*PP*	*KPSS*	*EG*	*Test de Johansen*	
				λ-trace	*N*
Panel a. Developed countries					
Australia	-2.46	0.05*	-2.20	17.78	0
Belgium	-2.14	0.12†	-2.03	4.83	1
Belgium-€	-2.18	0.18‡	-3.42	3.44	0
Canada	-1.82	0.07*	-2.53	10.20	0
Denmark	-2.51	0.08*	-2.22	3.67	1†
France	-2.35	0.07*	-2.50	4.12	1‡
France-€	-3.18	0.06*	-3.14	9.60	0
Germany	-2.14	0.14†	-2.13	9.68	0
Germany-€	-3.10	0.12†	-2.14	9.71	0
Italy	-2.25	0.11*	-2.44	7.17	0
Italy-€	-1.31	0.19	-1.27	10.78	0
Japan	-2.38	0.12†	-2.53	5.47	1†
Luxembourg	-2.10	0.13†	-1.99	7.74	0
Luxembourg€	-2.37	0.17‡	-2.37	0.60	0
New-Zealand	-2.40	0.09*	-2.57	7.85	1†
Norway	-2.57	0.06*	-2.44	3.81	0
Sweden	-2.52	0.05*	-2.39	10.17	0
Switzerland	-2.76	0.07*	-2.68	1.511	1†
UK	-2.57	0.20‡	-2.38	0.15	0
Panel b. Emerging countries					
Korea	-2.35	0.12*	-2.69	5.84	1†
India	-3.44	0.11*	-2.79	0.53	1
Indonesia	-3.70	0.11*	-3.37	2.32	0
Malaysia	-4.21	0.11*	-3.72	2.03	1
Mexico	-2.94	0.21‡	-2.75	2.28	1†
Paraguay	-2.66	0.10*	-2.54	8.85	0
Philippines	-2.72	0.10*	-2.59	12.60	0
Singapore	-1.98	0.14†	-1.92	6.146	1
Thailand	-3.17	0.14†	-3.30	10.86	1†

Notes: € : post euro period (1999 :Q1-2005 : Q2). PP: Philipps & Perron, 1988; test statistic. KPSS: Kiatkowski, Phillips, Schmidt & Shin, 1992; test statistic, EG: Engle & Granger, 1987; test statistic. λ-trace: trace test statistic of Johansen, 1988; and N : number of cointegration relation.*, † et ‡ denote significant at 10%, 5% and 1% levels respectively.

The obtained results are in contradiction with Engle-Granger conclusions. More precisely, the Johansen procedure provides evidence of linear cointegration among nominal exchange rates and domestic and foreign consumer price series for 5 developed countries: Denmark, France for pre-euro period, Japan, New-Zealand, and Switzerland) and 6 emerging counties: Korea, India, Malaysia, Mexico, Singapore, and Thailand. Our results are quite similar to Baum, Barkoulas & Caglayan, 2001; conclusions. Using the Johansen procedure for a sample covering 17 developed countries for the period 1973-1995, the authors found evidence of linear cointegration between the three variables for only 11 countries (Baum, Barkoulas & Caglayan, 2001; p. 387).

5.3. Linearity tests of deviations from PPP

We use equation (5) to include the delay order (p) in order to specify the autoregressive process of deviations from PPP. The lag length for each country series is chosen on the bases of the Akaike and Schwarz information criteria and the partial autocorrelation functions. For all emerging and developed countries, we choose $p = 1$. This choice is approved by Durbin and Watson, 1951; and Ljung & Box, 1978; residual autocorrelation tests. Also, White, 1980; and Engle, 1982; provide no evidence of residuals heteroscedasticity. Table 4 presents the autoregressive process estimations. The residual diagnostic tests are reported in table 5.

Table 4.
Estimation results of the linear model for deviations from PPP

Model : $y_t = k^{'} + \lambda^{'} d_{t-1} + \phi^{'} y_{t-1} + v_t$

Countries	$k^{'}$		$\lambda^{'}$		$\phi^{'}$	
	$\hat{k}^{'}$	t.stat	$\hat{\lambda}^{'}$	t.stat	$\hat{\phi}^{'}$	t.stat
Panel a. Developed countries						
Australia	0.01	1.80†	-0.04	-1.88†	0.18	2.11†
Belgium	0.001	0.54	-0.01	-1.93†	0.27	3.20†
Belgium€	-0.006	-0.63	-0.02	-0.32	0.12	0.54
Canada	0.006	1.67†	-0.02	-1.56*	0.28	3.35†
Denmark	0.10	2.12†	-0.05	-2.14†	0.25	2.93†
France	0.12	2.34†	-0.07	-2.32†	0.35	3.79†
France€	-0.004	-0.44	-0.03	-0.42	0.13	0.60
Germany	0.03	2.04†	-0.06	-2.10†	0.27	2.89†
Germany€	0.001	0.54	-0.01	-1.93†	0.27	3.20†
Italy	0.53	2.29†	-0.07	-2.29†	0.32	3.35†
Italy€	-0.007	-0.78	-0.02	-0.31	0.17	0.82
Japan	0.21	2.04†	-0.04	-2.06†	0.24	2.93†
Luxembourg	0.10	1.36*	-0.02	-1.41*	0.30	3.19†
Luxembourg€	-0.005	-0.54	-0.27	-0.41	0.30	1.41*
New-Zealand	0.03	2.22†	-0.05	-2.33†	0.36	4.38†
Norway	0.13	2.32†	-0.06	-2.33†	0.23	2.69†
Sweden	0.07	1.81†	-0.03	-1.78†	0.25	2.96†
Switzerland	0.03	2.29†	-0.07	-2.55†	0.26	3.15†
UK	0.02	2.44†	-0.04	-3.26†	0.19	2.38†
Panel b. Emerging countries						
Korea	0.45	2.45†	-0.06	-2.45†	0.30	3.55†
India	0.04	1.54*	-0.01	-1.38*	0.30	3.73†
Indonesia	0.15	1.21	-0.01	-1.17	0.22	2.55†
Malaysia	0.01	1.22	-0.009	-0.89	0.37	4.59†
Mexico	0.14	2.37†	-0.09	-2.36†	-0.11	-1.25
Paraguay	0.15	1.24	-0.01	-1.02	0.40	4.88†
Philippines	0.08	1.34*	-0.02	-1.32	0.26	3.09†
Singapore	0.01	1.74†	-0.03	-1.64†	0.27	3.43†
Thailand	0.07	1.22	-0.02	-1.18	0.029	3.48†

Notes: €: post euro period (1999 : Q1-2005 : Q2). t.stat: Student test statistic.*, † and ‡ denote significant at 10%, 5% and 1% levels respectively.

Table 5.
Residuals diagnostics results

Countries	Autocorrelation			HET	ARCH (1)
	DW	*DURBIN' h*	$Q[6]$		
Panel a. Developed countries					
Australia	2.02	-0.11	8.63*	3.08*	5.85†
Belgium	1.98	0.08	9.06*	0.001*	1.62
Belgium-€	2.03	-0.08	8.22*	0.71*	4.69†
Canada	1.98	0.06	16.92	2.89v	13.05 ‡
Denmark	2.02	-0.12	9.29*	2.12*	3.17*
France	1.98	0.10	3.35*	0.004*	1.31
France-€	2.03	-0.09	8.40*	0.79*	5.07†
Germany	1.99	0.01	9.55*	4.49*	1.46
Germany-€	2.02	-0.05	8.98*	0.63*	5.19†
Italy	1.95	0.24	5.52*	2.54*	20.45 ‡
Italy-€	2.02	-0.05	10.29*	0.01*	2.26
Japan	1.93	0.38	12.34†	0.14*	3.44*
Luxembourg	2.00	-0.03	5.77*	0.22*	1.06
Luxembourg€	2.05	-0.13	9.97*	1.35*	5.30†
New-Zealand	2.10	-0.59	13.86†	2.22*	4.24†
Norway	1.98	0.07	8.99*	2.32*	4.52†
Sweden	2.02	-0.15	13.32†	7.42†	7.20†
Switzerland	1.98	0.11	6.29*	0.35*	1.62
UK	2.01	-0.10	8.05*	0.16*	1.85
Panel b. Emerging countries					
Korea	1.91	0.48	6.58*	2.45*	55.24 ‡
India	1.89	0.60	18.25	4.42*	16.39 ‡
Indonesia	2.03	-0.21	15.38†	7.89†	19.66 ‡
Malaysia	1.92	0.43	4.41*	9.38 ‡	14.10 ‡
Mexico	1.98	0.08	6.05*	2.37*	17.72 ‡
Paraguay	1.75	1.38	18.89	1.245*	25.55 ‡
Philippines	2.07	-0.41	9.67*	24.91 ‡	41.70 ‡
Singapore	2.14	-0.83	9.43*	5.17*	33.42 ‡
Thailand	1.98	0.07	14.94†	7.72†	24.41 ‡

Notes: €: post euro period (1999:Q1-2005:Q2). DW: Durbin & Watson, 1951; test statistic. Durbin'h : Durbin, 1970; test statistic. Q [6]: Ljung-Box, 1979; statistics up to 6 orders. HET: White, 1980; test statistic. ARCH (1): Engle, 1982; test statistic.*, † et ‡ denote significant at 10%, 5% and 1% levels respectively.

5.4. Tests for nonlinearity

The nonlinearity tests and subsequent analysis are applied to the serial of deviations from PPP as estimated the Engle & Granger, 1987; and Johansen, 1998; methods. As in previous empirical studies, we assimilate, hereafter, these series to real exchange rates. We use the LST, 1988; test to determinate the optimal delay parameter $\hat{r}$. Following Baum, Barkoulas & Caglayan, 2001; Chen, 2003; and Liew, Chong & Lim, 2003; the optimal delay parameter is chosen by maximising the $LM(r)$ statistics of the linearity test over the range {1,2,..,12}. We have also used F_1 , F_2 and F_3 (Anderson & Teräsvirta ; 1992 and Teräsvirta ; 1994) statistics in order to discriminate between LSTAR and ESTAR models. LST test results for emerging and developed countries are respectively presented in Table 6.

The results found in the table show that the null hypothesis of linearity is accepted for 7 developed countries (5 European countries for the post-euro period: Germany, Belgium, France, Italy, and Luxembourg; Japan and Canada) and 2 emerging countries (India and Mexico). The null hypothesis of linearity is rejected in favour of LSTAR or ESTAR specifications. For eleven countries, we reject linearity in favour of the ESTAR specification. The LSTAR process was retained for 4 developed countries (France for the period pre-euro, Denmark, Sweden, and Switzerland) and 4 emerging countries (Korea, Indonesia, Paraguay, and Singapore).

Table 6.
Linearity tests results

Countries	$MaxLM(r)$	(p)	(r)	Process
Panel a. Developed countries				
Australia	19.31	1	9	ESTAR
Belgium	15.10	1	11	ESTAR
Belgium-€	15.46	1	11	AR
Canada	15.15	1	6	AR
Denmark	14.01	1	9	LSTAR
France	17.01	1	9	LSTAR
France-€	14.36	1	11	AR
Germany	22.01	1	12	ESTAR
Germany-€	15.52	1	12	AR
Italy	9.79	1	11	ESTAR
Italy-€	18.01	1	11	AR
Japan	3.68	1	7	AR
Luxembourg	17.73	1	11	ESTAR
Luxembourg-€	17.31	1	12	AR
New-Zealand	19.82	1	10	ESTAR
Norway	13.94	1	9	ESTAR
Sweden	32.20	1	11	LSTAR
Switzerland	10.58	1	10	LSTAR
UK	8.97	1	9	ESTAR
Panel b. Emerging countries				
Korea	36.69	1	2	LSTAR
India	25.90	1	12	AR
Indonesia	22.32	1	3	LSTAR
Malaysia	36.36	1	3	ESTAR
Mexico	2.72	1	3	AR
Paraguay	35.15	1	10	LSTAR
Philippines	26.80	1	4	ESTAR
Singapore	41.29	1	12	LSTAR
Thailand	37.88	1	3	ESTAR

Notes: € : post euro period (1999 : I-2005 : II). $MaxLM(r)$: Maximum of Luukkonen, Saikkonen & Teräsvirta, 1988; test statistic. (r) : optimal delay parameter. (p) : lag length.

5.5. Nonlinear cointegration tests

According to the results of the linearity test we propose to check the nonlinear stationarity property of RER series. We use Kapetanios, Shin & Snell, 2003a; (KSS) test for ESTAR specification and Eklund, 2003; test for LSTAR model. Kapetanios, Shin & Snell, 2003a; propose a testing procedure to detect the presence of nonstationarity against non-linear but globally stationary ESTAR process. The authors reparameterised ESTAR model based on Taylor series approximation to obtain

$$\Delta d_t = \delta d_{t-1}^3 + erreur \quad (10)$$

After estimating equation (10) by OLS, they propose the KSS test statistic $t_{nl} = \hat{\delta} / \hat{\sigma}_{\hat{\delta}}$ under the null hypothesis (H_0: $\gamma = 0$). In order to correct for plausible serially errors, they propose augmented KSS test (AKSS) based on the estimation of the following regression:

$$\Delta d_t = \sum_{j=1}^{p} \rho_j d_{t-j} + \delta d_{t-1}^3 + erreur \quad (11)$$

And calculate the statistic as above t_{nl} of AKSS.

Kapetanios, Shin & Snell, 2003a; apply their tests to real exchange rates from the eleven major OECD economies and we also estimate the alternative ESTAR models (Kapetanios, Shin & Snell, 2003a; p. 376). These tests are used in previous empirical studies such as Chortareas & Kapetanios, 2003; Liew, Chong & Lim, 2003; Cheung, Lai & Bergman, 2004; and 2005; Baharumshah, Liew & Lau, 2003; Maki, 2004; and Bec, Guay & Guerre, 2002; and Bec, Ben Salem & Rahbek, 2003. In this study we employ the nonlinear KSS tests and the ADF, PP and KPSS tests results for the purpose of comparison. The results of applying both the linear and nonlinear unit root tests are summarized in Table 7.

Table 7.
Linear and nonlinear stationary tests results

Countries	ADF	PP	KPSS	KSS	AKSS
Panel a. Developed countries					
Australia	-1.88	-1.83	0.81	-8.08 ‡	-5.77 ‡
Belgium	-1.91	-1.95	0.15	-6.16 ‡	-4.96 ‡
Germany	-2.09	-2.08	0.15‡	-7.65 ‡	-6.86 ‡
Italy	-2.29	-2.13	0.26	-3.73 ‡	-2.48
Luxembourg	-1.41	-1.61	0.68	-6.18 ‡	-4.78 ‡
New-Zealand	-2.63	-2.17	0.10‡	-5.01 ‡	-3.21 †
Norway	-2.33	-2.31	0.17‡	-6.78 ‡	-5.10 ‡
UK	-3.11	-2.92	0.95	-5.47 ‡	-3.33 †
Panel b. Emerging countries					
Malaysia	-0.89	-0.34	1.28	-3.62‡	-3.08†
Philippines	-1.32	-1.30	0.77	-8.24‡	-6.20‡
Thailand	-1.18	-0.93	1.07	-4.22‡	-2.60*

Notes: ADF: augmented Dickey & Fuller, 1981; test statistic. PP: Philipps & Perron, 1988; test statistic. KPSS: Kiatkowski, Phillips, Schmidt & Shin, 1992; test statistic. KSS and AKSS: Kapetanios, Shin & Snell, 2003a; test statistics. The 1%, 5% and 10% critical values for both KSS and AKSS are, –3.48, –2.93, –2.55 respectively .*, † et ‡ denote significant at 10%, 5% and 1% levels respectively.

As observed in tables that there is no sign of stationarity in all the real exchange rates by the linear ADF, PP and KPSS test statistics. Whereas the nonlinear KSS and AKSS test statistics show otherwise. The RER series are stationary to be precise, nonlinear stationary (Liew, Chong & Lim, 2003; p.16). We conclude that RER follows a nonlinear exponential smooth transition autoregressive (ESTAR) process, which is globally stationary (Kapetanios, Shin & Snell, 2003a; p.360). Furthermore, the nominal exchange rate series are nonlinear cointegrated with the relative price. Our results are conforming to those of Liew, Chong & Lim, 2003; with Malaysian Ringgit and Baharumshah, Liew & Lau, 2003; with Indonesia.

We propose another nonlinear stationary test of Eklund, 2003a; to detect non-linear but globally stationary LSTAR process. The author proposes the Taylor series approximation of the LSTAR model and obtains the following regression:

$$y_t = \alpha + \rho y_{t-1} + \delta_1 \Delta y_{t-1} + \delta_2 (\Delta y_{t-1})^2 + \delta_3 (\Delta y_{t-1})^3 + \phi_1 y_{t-1} \Delta y_{t-1} + \phi_2 y_{t-1} (\Delta y_{t-1})^2 \qquad (12)$$

Test the null hypothesis (H_0: $\gamma = 0$) correspond to test $\delta_2 = \delta_3 = \phi_1 = \phi_2 = 0$. Eklund, 2003 a, b; proposes two statistics F_{ND} and F_D to test respectively the null hypothesis:

$$H_{01}: \delta_2 = \delta_3 = \phi_1 = \phi_2 = \alpha = 0, \rho = 1 \qquad (13a)$$

and,

$$H_{02}: \delta_2 = \delta_3 = \phi_1 = \phi_2 = 0, \rho = 1 \qquad (13b)$$

The results of linear and non linear stationary tests are reported in Table 8.

Table 8.
Linear and nonlinear stationary tests results

Countries	*ADF*	*PP*	*KPSS*	F_{ND}	F_D
Panel b. Developed countries					
Denmark	-2.14	-2.34	0.08‡	12.82‡	10.69‡
France	-2.32	-2.12	0.12†	10.20‡	8.50‡
Sweden	-1.78	-1.83	0.50	11.68‡	9.74‡
Switzerland	-2.55	-2.70	0.25	13.21‡	11.02‡
Panel b. Emerging countries					
Korea	-2.45	-2.10	0.32	28.07‡	23.39‡
Indonesia	-0.89	-0.93	1.23	13.32‡	4.30‡
Paraguay	-0.59	-0.61	1.07	24.93‡	20.77‡
Singapore	-1.22	-1.76	0.36	21.24‡	17.78‡

Notes: ADF: augmented Dickey & Fuller, 1981; test statistic. PP: Philipps & Perron, 1988; test statistic. KPSS : Kiatkowski, Phillips, Schmidt & Shin, 1992; test statistic. F_{ND} and F_D : Eklund, 2003a; test statistics. The 1%, 5% and 10% critical values for both F_{ND} and F_D are, 3.43, 2.6 and 2.22 ; 3.9, 2.9 and 2.45 respectively .*, † et ‡ denote significant at 10%, 5% and 1% levels respectively.

For all the real exchange rates, we reject the hypothesis of linear stationary by the linear ADF, PP and KPSS test statistics. Nevertheless, we conclude that the RER follows a nonlinear LSTAR process, which is globally stationary. Consequently, the nominal exchange rate series are nonlinear cointegrated with the relative price. Our results are in line with Eklund, 2003b; findings.

5.6. STAR models estimations

The resulting ESTAR/LSTAR models, estimated by QMLE are summarised in Tables 9 and 10. Diagnostic tests are applied to the estimated STAR models are reported in Tables 11 and 12. In particular, we present the stationary ADF, PP and KPSS tests, the Jarque-Béra normality test (Jarque & Béra, 1980), Durbin & Watson, 1951; and Ljung & Box, 1978; residual autocorrelation tests and the heteroscedasticity test of White, 1980; and the ARCH test of Engle, 1982. In addition, we present tests designed by Granger & Teräsvirta, 1993; and Eitrheim & Teräsvirta, 1996.

The test hypothesis of Granger & Terasvirta, 1993; are given by:

$H_0^A : k = k^* = c = 0$;

$H_0^B : 1 + \lambda^{'} = -\lambda^{''}; \phi^{'} = -\phi^{''}$ where H_0^A is verified;

$H_0^C : \lambda^{'} = 0$ and H_0^A where H_0^A and H_0^B are verified.

Eitrheim & Teräsvirta, 1996; propose three misspecification tests for univariate STAR models of: residual autocorrelation, constancy parameters over time and no remaining nonlinearity.

The estimated values of (c) are between the smaller and the greater values of the transition variable for all countries excepting Germany, Thailand, Philippines, Belgium, Korea, France, and Sweden. The constants k and k*, are distinguished from zero, for all countries except Germany and Paraguay. Thus, the deviations from PPP in the outer regime do not die out quickly and there is a significant degree of persistence in the outer regime. The hypothesis H_0^B is satisfied for 11 countries: Germany, Australia, Belgium, UK, Luxembourg, and New-Zealand with ESTAR models; Denmark, France, Korea, Paraguay, and Singapore with LSTAR models. Consequently, the STAR models are stable and the deviations from PPP are nonlinearly mean reverting in the outer regime. The coefficient γ given the value of the transition speed between the extreme regimes is significantly different from zero for twelve countries and the hypothesis H_0^C is satisfied for the whole countries. Hence, the deviations in the middle regime have an explosive dynamic for small deviations. In conclusion, we can say that the deviations from PPP follow an explosive behaviour in the middle regime and a nonlinearly mean-reverting process in the outer regime. The residual diagnostics tests (stationary, autocorrelation, normality and heteroscedasticity) are satisfactory in all cases except we detect ARCH effect for Paraguay, Korea, Malaysia, and Philippines. We must estimate a STAR-ARCH model. Regarding the results of tests of Eithreim & Teräsvirta,1996; the STAR models appear to provide a satisfactory representation for the non linear adjustment of the PPP's deviations.

TABLE 9.
Estimation results of LSTAR model for deviations from PPP

Model: $y_t = \left(k + \lambda d_{t-1} + \phi y_{t-1}\right) + \left[k^* + \lambda^* d_{t-1} + \sum_{i=1}^{p} \phi_i^* y_{t-i}\right] F\left(y_{t-r}; c; \gamma\right) + u_t$

Countries	(p)	(d)	k		λ		ϕ		k^*		λ^*		ϕ^*		c		γ		R^2
			$\hat{k}$	t.stat	$\hat{\lambda}$	t.stat	$\hat{\phi}$	t.stat	$\hat{k}^*$	t.stat	$\hat{\lambda}^*$	t.stat	$\hat{\phi}^*$	t.stat	$\hat{c}$	t.stat	$\hat{\gamma}$	t.stat	
Panel a. Developed countries																			
Denmark	1	9	-1.45	-1.11	-0.12	-2.15 †	0.13	0.88	0.80	0.54	0.12	1.704†	0.27	1.36*	7.24	0.81	9.00	10.31‡	0.15
France	1	9	-0.27	-0.30	-0.10	-1.65 †	-0.04	-0.25	0.18	0.17	0.07	1.06	0.61	2.75‡	7.19	3.87‡	0.90	2.02†	0.25
Sweden	1	11	23.88	0.005	-2.01	-0.005	-4.61	-0.004	-23.59	-0.005	1.99	0.005	4.95	0.005	6.94	3.06‡	7.00	6.71‡	0.13
Switzerland	1	10	-3.42	-2.14 †	-0.11	-2.67‡	0.14	1.29*	2.42	1.10	0.10	1.63*	0.27	1.49*	6.79	0.31	9.00	1.61*	0.15
Panel b. Emerging countries																			
Korea	1	2	-2.27	-1.13	-0.03	-0.34	-0.18	-0.37	1.81	0.87	-0.04	-0.40	0.50	1.01	10.63	2.04†	9.00	4.14‡	0.13
Indonesia	1	3	-1.77	-0.75	0.013	0.41	-0.02	-0.13	4.61	1.53*	-0.06	-1.48*	0.33	1.53*	15.98	1.48*	8.00	3.87‡	0.10
Paraguay	1	10	0.60	0.97	-0.02	-1.34*	0.32	3.38‡	13.72	4.17‡	-0.48	-4.13‡	0.44	2.24‡	10.79	1.03	9.00	0.00006	0.36
Singapore	1	12	-2.27	-1.13	-0.03	-0.34	-0.18	0.37	1.81	0.87	-0.04	-0.40	0.50	1.01	1.52	0.20	9.00	1.68†	0.14

Note s: (r) : optimal delay parameter. (p) : lag length. R^2 : coefficient of determination .*, † et ‡ denote significant at 10%, 5% and 1% levels respectively.

TABLE 10.

Estimation results of ESTAR model for deviations from PPP

Model: $y_t = \left(k + \lambda d_{t-1} + \phi y_{t-1}\right) + \left[k^* + \lambda^* d_{t-1} + \sum_{i=1}^{p} \phi_i^* y_{t-i}\right] F\left(y_{t-r}; c; \gamma\right) + u_t$

Countries	(p)	(d)	k		λ		ϕ		k^*		λ^*		ϕ^*		c		γ		R^2
			$\hat{k}$	t.stat	$\hat{\lambda}$	t.stat	$\hat{\phi}$	t.stat	$\hat{k}^*$	t.stat	$\hat{\lambda}^*$	t.stat	$\hat{\phi}^*$	t.stat	$\hat{c}$	t.stat	$\hat{\gamma}$	t.stat	
Panel a. Developed countries																			
Australia	1	9	-243.7	-0.55	-5.93	-0.47	-43.38	-0.51	244.7	0.55	5.90	0.47	43.57	0.51	5.95	0.16	9.00	0.21	0.16
Belgium	1	11	-38.43	-0.49	-2.30	-0.65	30.42	1.73†	38.28	0.48	2.25	0.63	-30.19	-1.71†	6.45	2.82‡	9.00	1.42*	0.20
Germany	1	12	-6.8	-0.07	-12.8	-0.3	15.4	0.3	6.6	0.06	13.2	0.3	-15.6	-0.29	3.91	25.2‡	0.10	5.69‡	0.19
Italy	1	11	27.02	0.62	4.36	0.57	11.13	0.86	-27.18	-0.62	-4.44	-0.58	-10.82	-0.84	6.39	0.92	3.005	0.81	0.15
Luxembourg	1	11	-279.2	-2.04 †	-5.70	-1.88 †	24.72	1.68	278.52	2.03 †	5.68	1.87†	-24.44	-1.66*	6.83	0.70	4.02	0.96	0.20
New-Zealand	1	3	13.29	1.27	-0.26	-0.80	21.53	7.66‡	-13.43	-1.22	0.27	0.77	-22.13	-7.53‡	2..89	0.26	9.83	0.60	0.42
Norway	1	10	-4.11	-0.15	2.519	1.26	13.98	2.26 †	3.35	0.12	-2.60	-1.30*	-13.89	-2.23	7.41	1.18	5.00	1.62*	0.16
UK	1	9	-582.8	-1.37*	-6.62	-1.40	4.06	0.23	578.1	1.36*	6.57	1.39*	-3.88	-0.22	5.49	0.83	5.001	1.03	0.18
Panel a. Developed countries																			
Malaysia	1	9	-82.19	-1.54	1.05	0.32	-26.21	-1.46	82.49	1.55	-1.10	-0.34	26.66	1.49	3.49	0.26	9.58	0.54	0.21
Philippines	1	4	-38.47	-0.88	-0.95	-0.31	24.93	1.93 †	38.79	0.89	0.94	0.30	-24.79	-1.92 †	23.95	21.23‡	0.10	2.02 †	0.15
Thailand	1	3	-9.74	-0.11	3.96	1.55	21.17	2.56‡	10.82	0.12	-4.22	-1.55	-21.93	-2.49‡	7.74	11.14‡	0.006	1.49	0.40

Notes: (r) : optimal delay parameter. (p) : lag length. R^2 : coefficient of determination .*, † et ‡ denote significant at 10%, 5% and 1% levels respectively.

Table 11.
Residual diagnostics results of LSTAR models

Countries	ADF	PP	KPSS	JB	DW	Q(6)	White	ARCH(1)
Panel b. Developed countries								
Denmark	-10.18	-10.15	0.09	1.7	2.04	9.11	5.59	1.33
France	-12.36	-12.29	0.10	2.90	2.11	5.70	9.33	0.00
Sweden	-10.69	-10.68	0.23	9.18	2.06	10.65	6.55	4.76
Switzerland	-10.59	-10.59	0.07	2.02	1.96	8.14	3.27	1.08
Panel b. Developed countries								
Korea	-10.47	-10.44	0.18	1291.3	1.87	7.32	67.68	54.43
Indonesia	-12.25	-12.42	0.42	985.0	2.06	12.05	27.12	15.63
Paraguay	-5.05	-8.53	0.50	115.2	1.56	22.49	16.44	12.63
Singapore	-10.89	-10.91	0.14	0.08	2.02	9.51	7.43	1.29

Notes: ADF: augmented Dickey & Fuller, 1981; test statistic. PP: Philipps & Perron, 1988; test statistic. KPSS : Kiatkowski, Phillips, Schmidt & Shin, 1992.JB: Jarque & Béra, 1980; test statistic. DW : Durbin & Watson, 1951; test statistic. Q [6]: Ljung & Box, 1979; statistics up to 6 orders. HET: White, 1980; test statistic. ARCH (1) : Engle, 1982; test statistic.

Table 12.
Residual diagnostics results of ESTAR models

Countries	ADF	PP	KPSS	JB	DW	Q(6)	White	ARCH(1)
Panel a. Emerging countries								
Australia	-11.38	-11.37	0.14	15.80	2.08	4.41	10.06	5.44
Belgium	-9.36	-9.37	0.08	1.876	1.98	5.07	0.94	0.511
Germany	-9.98	-9.98	0.08	1.21	2.12	4.62	2.37	0.91
Italy	-9.43	-9.44	0.21	14.46	1.88	7.10	18.01	2.07
Luxembourg	-9.63	-9.63	0.20	2.194	2.03	5.31	0.59	1.11
New-Zealand	-11.06	-11.06	0.08	162.5	2.05	12.74	5.33	0.14
Norway	-10.99	-10.99	0.09	1.293	1.97	9.01	4.73	0.72
UK	-11.53	-11.54	0.06	28.06	2.10	8.11	1.816	0.09
Panel b. Emerging countries								
Malaysia	-10.18	-10.15	0.09	44.8	1.82	10.51	12.83	11.42
Philippines	-12.36	-12.29	0.10	69.8	2.22	13.06	32.31	15.15
Thailand	-10.69	-10.68	0.23	2166.8	1.91	4.89	0.55	0.54

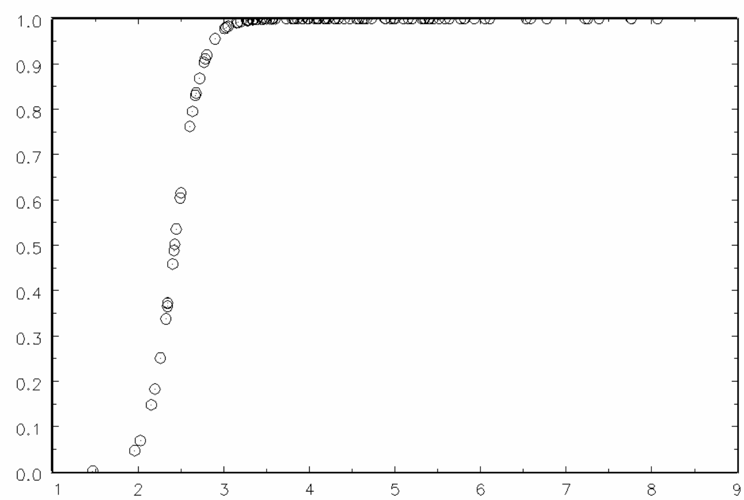
Notes: ADF: augmented Dickey & Fuller, 1981; test statistic. PP: Philipps & Perron, 1988; test statistic. KPSS : Kiatkowski, Phillips, Schmidt & Shin, 1992.JB: Jarque & Béra, 1980; test statistic. DW : Durbin & Watson, 1951; test statistic. Q [6]: Ljung & Box, 1979; statistics up to 6 orders. HET: White, 1980; test statistic. ARCH (1) : Engle, 1982; test statistic.

A. The estimated transition functions

We present the graphics of the estimated transition functions (equations (5) and (6)) against the transition variable to gauge the degree of nonlinear adjustment of the deviations from the PPP. As suggested by Taylor and Peel (2000) “the value of the transition function is a measure of the importance of the deviation from equilibrium’ (Taylor and Peel, 2000, p. 48). Plots of estimated transitions functions versus time for all emerging and developed countries are not reported here, they are available upon request.

Figure 1.
Plots of estimated logistic transition functions versus transition variable for Denmark and Singapore

Denmark



Singapore

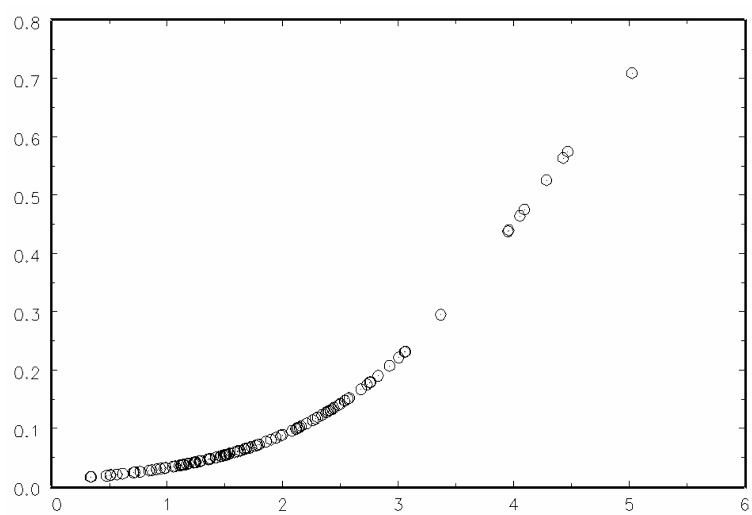
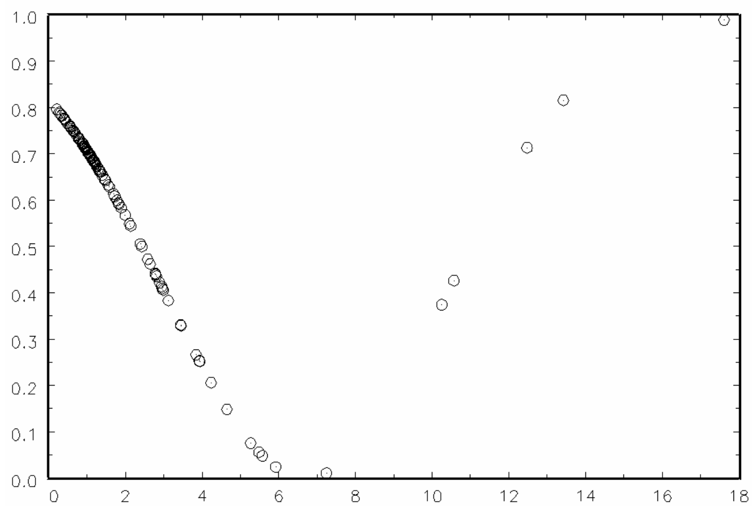


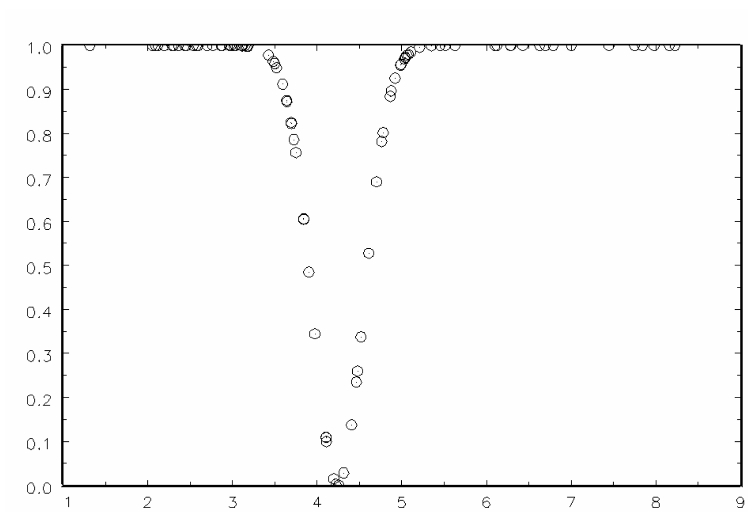
Figure 2.

Plots of estimated exponential transition functions versus transition variable for Thailand and Luxembourg

Thailand



Luxembourg (pre-euro period)



As shown in figures 1 and 2, the speed of adjustment in the middle regime is faster in the case of developed countries than the emerging countries. This result is consistent with Liew, Chong & Lim, 2003; for the Malaysia, and Baharumshah, Liew & Lau, 2003; with Thailand and Philippines and Baum, Barkoulas & Caglayan, 2001; Taylor, Peel & Sarno, 2001; and Micheal, Nobay & Peel, 1997; for developed countries. In other words, the slopes of the transition functions are greater for the developed countries which indicate that convergence back to PPP is very quickly. Whereas, for small deviations from PPP, in the middle regime, the RER of emerging countries return to each equilibrium level in the long run. As from plots of estimated transition functions versus time, we can see that the RER adjust constantly and smoothly between the extreme regimes of the STAR models for all countries.

B. The estimated generalized impulse response functions

In this study, we study the dynamic of the dynamic structure of the real exchange rate. As mentioned by Taylor, Peel & Sarno, 2001; “ with nonlinear models, the shape of impulse response function is not independent with respect to either the history of the system at the time the shock occurs, the size of the shock considered, or the distribution of the future exogenous innovations” (Taylor, Peel & Sarno, 2001; p. 1033). Following the previous studies, we propose to the generalized impulses responses functions (GIRF) discussed Gallant, Rossi & Tauchen, 1993.They propose this procedure to estimate the GIRF for the nonlinear models given by:

$$GIRF_h(h,\delta,w_{t-1}) = E(y_{t+h}|\varepsilon_t = \delta, w_{t-1}) - E(y_{t+h}|\varepsilon_t = 0, w_{t-1}) \quad (14)$$

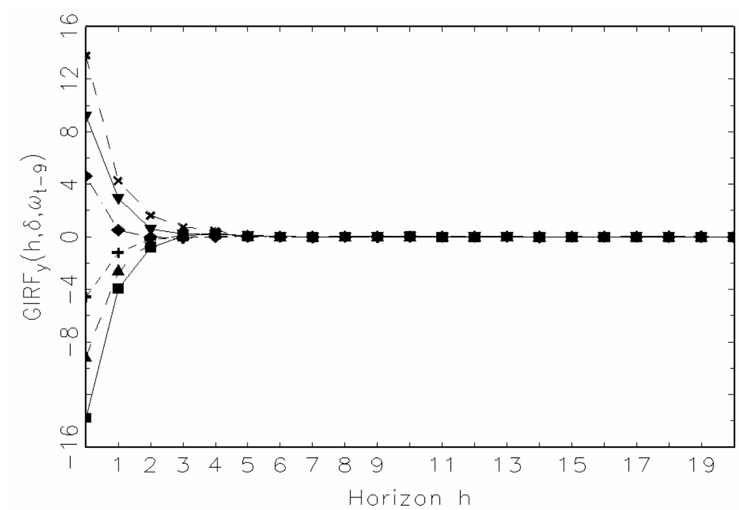
Where, $h = 0,1,2,..,12$ is the forecasting horizon in our case; $\varepsilon_t = \delta$ is exogenous shock or a perturbation to the RER at time (t); w_{t-1} is the conditioning information set (or initial conditions of the variable y_t) at time (t-1). The conditional forecasts are simulated realizations obtained by iterating the time series model, randomly drawing with replacement from the estimated residuals of the STAR model, and then averaging over 5000 draws (see Gallant, Rossi & Tauchen, 1993; Taylor, Peel & Sarno, 2001; Baum, Barkoulas & Caglayan, 2001; for details).

Figures 3 and 4 present the plots of estimated generalized impulse response functions for United Kingdom with ESTAR model and France for the pre-euro period with LSTAR model. Figures 3b give the same plots for Philippines and Korea with respectively ESTAR and LSTAR process. We employ six sizes of shock given by $\delta / \hat{\sigma}_{u_t} = \pm 5\%, \ \pm 9\%, \pm 13\%$, where $\hat{\sigma}_{u_t}$ is the standard deviation of the residuals of STAR models. Plots of estimated GIRF versus time for all emerging and developed countries are not reported here, they are available upon request.

The exam of the graphs gives us the following conclusions: i) the dynamic of the RER to innovations is a nonlinear mean-reverting process; ii) the GIRF is affected by the size of shocks. The GIRF for the developed countries decline very quickly for a larger shock $(\pm 13\%)$ than smaller shock $(\pm 5\%)$. Whereas, for the emerging countries, the GIRF decay slowly than the developed countries; iii) the GIRF is affected by the sign of shocks. This asymmetry is apparent with a positive and negative shock of equal magnitude in most cases. Our results are similar of those of Taylor & Peel; 2000; Taylor, Peel & Sarno, 2001; Baum, Barkoulas & Caglayan, 2001; Camarero & Ordonez, 2003; Peel & Venetis, 2005; Pesavento & Rossi, 2005; and Cheung, Lai & Bergman, 2004.

Figure 3.
Plots of estimated generalized impulse response functions for United Kingdom and France

United Kingdom



France (pre-euro period)

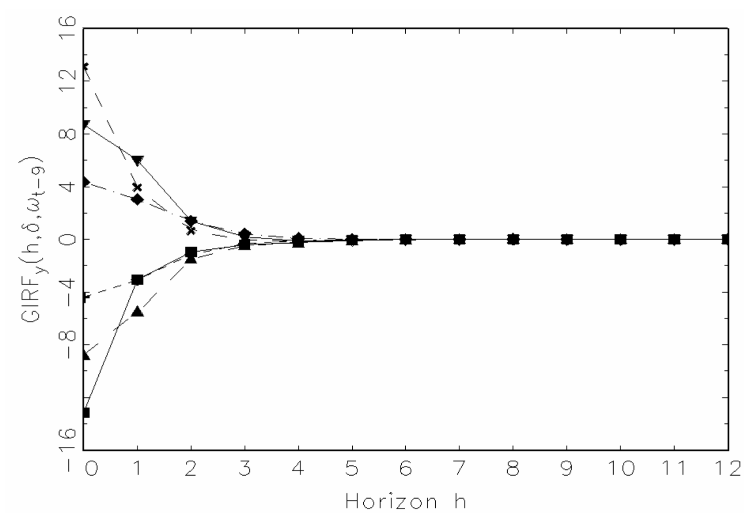
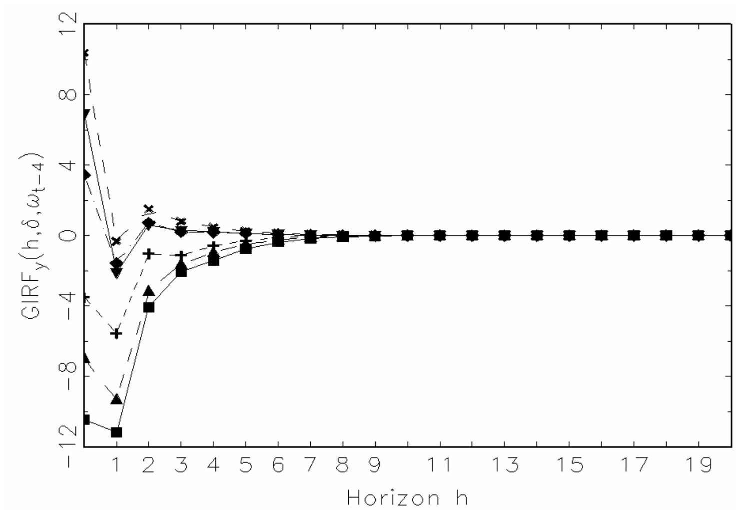
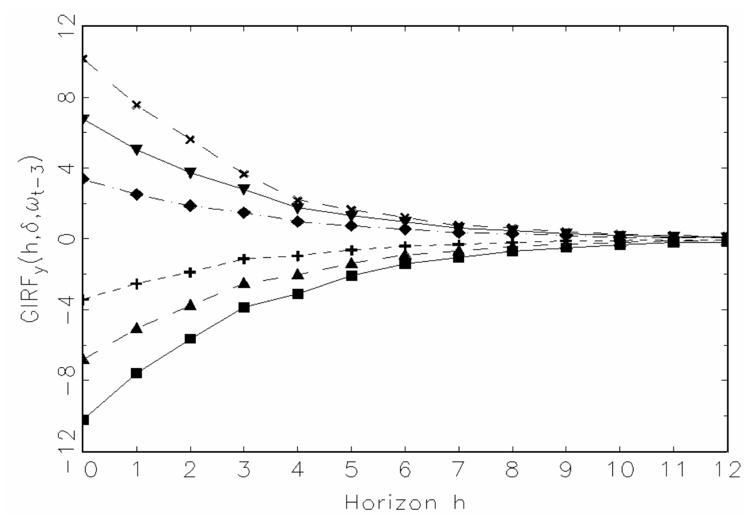


Figure 4.
Plots of estimated generalized impulse response functions for Philippines and Korea

Philippines



Korea



C. A forecasting performance comparison of nonlinear and linear models

In the earlier relevant literature, researchers propose to evaluate the forecasting performance of STAR model by taking the linear AR (p) as the benchmark. The out-of-sample performance of the estimated STAR models are evaluated over the forecast horizon of (H =5). The criterion is the ratio of forecast error measured in root mean square error (RMSE), with the forecast error of benchmark model as denominator. We use also the Granger & Newbold, 1986; test statistics given by:

$$W = \frac{1}{2}\left(\frac{(1+r)}{(1-r)}\right) \xrightarrow{asy} N\left(0,\left(\frac{1}{H-3}\right)\right) \quad (15)$$

Or we can use the following statistic

$$W^{*} = W / \left(\frac{1}{H-3}\right) \xrightarrow{asy} N(0,1) \quad (16)$$

With (r) is the ratio of the RMSE.

The results of forecasting accuracy comparison are grouped in Table 13 for developed and emerging countries.

Table 13.
Comparison of forecasting accuracy

Countries	r	W	W^{*}
Panel a. Developed countries			
Australia	0.67	2.56	5.13‡
Belgium	0.83	7.83	15.66‡
Denmark	1.05	17.74	35.48‡
France	1.04	24.30	48.61‡
Germany	0.78	8.09	16.18‡
Italy	1.17	6.18	12.36‡
Luxembourg	0.57	1.85	3.70‡
New-Zealand	1.25	4.50	9.00‡
Norway	0.96	28.91	57.82‡
Sweden	1.14	7.64	15.28‡
Switzerland	0.90	9.60	19.20‡
UK	2.08	1.42	2.85‡
Panel a. Emerging countries			
Indonesia	2.09	1.41	2.83‡
Korea	1.68	1.96	3.92‡
Malaysia	1.68	1.96	3.92‡
Paraguay	1.31	3.71	7.45‡
Philippines	1.08	12.12	24.25‡
Singapore	0.67	2.53	5.07‡
Thailand	1.18	5.81	11.63‡

Notes: r: ratio of RMSE. W and W* Granger & Newbold, 1986; test statistics.*, † et ‡ denote significant at 10%, 5% and 1% levels respectively.

Using the RMSE criteria, we conclude that STAR model, rather than the conventional AR model could better explain the future exchange rate behaviour. Our results are conforming to those of Baharumshah, Liew & Lau, 2003; for Asian countries. From the results of the Granger & Newbold, 1986; test, the STAR models continue to be greater than its linear counterpart.

5. Conclusion and policy implications

The majority of empirical investigations relative to PPP validity in developed and emerging countries based on linear tests for a long-run relationship between domestic prices, foreign prices and the nominal exchange rates. Most of these studies have been generally unsupportive of PPP. According to previous empirical studies, it is also argued that the sign and the size of any deviations from PPP are important with respect to any adjustment toward any long-run equilibrium. The transactions costs imply that the adjustment of RER is governed by a nonlinear mean-reverting process. In this paper, we fit exponential and logistic smooth autoregressive models in order to describe RER adjustment toward PPP as a fundamental long-run equilibrium relationship. Our empirical investigation was conducted on 23 emerging and developed countries. We use quarterly data covering the period (1973-2005). The sample period was subdivided in two sub-samples covering the pre and post euro periods. By allowing the presence of transactions costs, the obtained results show that the deviations from PPP are, for major countries, nonlinear. They can be described by ESTAR or LSTAR process. Our study provides additional evidence of nonlinear mean reverting process in RER adjustments toward PPP which tendency varying with sign and magnitude of deviations. The crucial estimated parameters of ESTAR and LSTAR process reveal that RER dynamics have two speeds inside and outside a band of inaction within which international price differentials are not arbitraged away. In this paper we have estimated the cumulative impulse functions for the levels of CPI based RER series corresponding to innovations in the vectors of initial conditions for ESTAR and LSTAR models. Evidence from these functions supports the nonlinearity in RER behaviour. More precisely, they show that the nonlinear adjustment is affected by the sign and the size of innovations. For developed countries, the real exchange rates have tendency to decline very quickly for large chocks. However, the GIRF decay very slowly in emerging countries. These results are consistent with a large number of recent theoretical contributions on the nature of RER dynamics in the presence of international arbitrage costs.

In line with previous empirical studies, we have evaluated the forecasting performance of STAR model by taking the linear process as a benchmark. Using the RMSE criteria and the Granger & Newbold, 1986; test, we conclude that STAR model, rather than the conventional AR model could better explain the future RER behaviour. Our results are quite similar to those in the empirical literature. In sum, our conclusions have major policy implications. First, our findings would seem to give some credence to emerging countries Central Banks in managing their domestic currencies in certain fluctuations bands in order to maintain relative currency stability or orderly market conditions. Second, in the short-run, nominal exchange rate may deviates from PPP equilibrium inside the inaction transaction band. However, outside the band market interventions will take place in order to force exchange rate to go back to the equilibrium level. Third, the nonlinear PPP equilibrium may be considered as a valid reference point for government policy makers in the evaluation of exchange rate over or under valuations and in the decision of policy responses. Forth, it will be very important to take into account nonlinearities in exchange rate behaviour in estimating more complicated monetary exchange models.

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