Stationarity of South Asian Real Exchange Rates Under Exponential Star (ESTAR) Framework

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STATIONARITY OF SOUTH ASIAN REAL EXCHANGE RATES UNDER EXPONENTIAL STAR (ESTAR) FRAMEWORK

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ABSTRACT

This paper investigates stationarity of four South Asian real exchange rates. In addition to the unit root tests that assume linearity in real exchange rate series, we apply tests to check stationarity that assume nonlinearity in a particular time series. Results from linear unit root tests (e.g. ADF and KPSS) unequivocally indicate that selected South Asian real exchange rates are all nonstationary. Different versions of a nonlinear unit root test, namely, the KSS tests, can only partially overturn these results. Overall, the real exchange rates of India, Pakistan and Sri Lanka seem to be conclusively nonstationary, while tests produce mixed results for Bangladesh. The findings have implications, among other, that PPP does not seem to characterize long run most real exchange rate movements in South Asia.

JEL Classification: F31, G15
Keywords: Real Exchange Rates, Nonlinear unit root tests, PPP, South Asia
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INTRODUCTION

The real bilateral exchange rates of many countries have been found to be nonstationary or unit root process. In that case, they meander away and do not tend to revert to a long run mean. This situation has implication, *inter alia*, for one of the much investigated relationship in international finance, namely, the Purchasing Power Parity (henceforth, PPP). The PPP, in its simplest version, postulates that currencies of different nations should be able to purchase the same amount of goods once converted into local currencies. The PPP is thought to be the truism under the perfect capital market that assumes existence of no transaction costs and continuous arbitrage in the spatially separated goods markets. In the way the real exchange rates are constructed, it means that the inflation differential between two countries will exactly be offset by an equivalent depreciation or appreciation in the bilateral nominal exchange rates leaving the real exchange rates unchanged. Over the time, therefore, one would expect that the real exchange rates would exhibit properties of a stationary time series that tend to be mean reverting.

A number of tests have been theoretically developed and empirically employed to detect the nonstationarity of real exchange rates around the world. These tests include both parametric ones (such as the augmented Dickey–Fuller (ADF) [Dickey and Fuller, 1981] and its variants like the ADF–GLS [Elliott *et al.* 1996] tests) and nonparametric tests (such as the Phillips and Perron (PP) [Phillips and Perron, 1988] test). A different type of unit root test is the KPSS test (Kwiatkowski et al., 1992) that assumes the null of stationarity unlike other tests that assume nonstationarity under the null. There are a number of papers that employ these techniques to test for PPP. In fact, as MacDonald (1996) notes, applying unit root tests on real exchange rates became a popular research activity in 1980s. Most notable early papers include Roll (1979), Adler and Lehmann (1983), Darby (1983), Hakkio (1984), Edison (1985), Frankel (1986), Huizunga (1987) and Meese and Rogoff (1988). Typically, most studies were unable to reject the null of nonstationarity for the major real exchange rates. Consequently, this rejection meant PPP did not hold in the long run. Rogoff (1996) termed this fact as “embarrassing” for researchers. This finding also invalidated the widely accepted theory of the monetary neutrality in the long run.

The tests that have been traditionally applied, as outlined above, assume that the real exchange rates exhibit linear movements. But, researchers now increasingly believe that real exchange rates exhibit nonlinearity rather than linearity. Taylor et al. (2001) discuss different plausible sources of nonlinearity in real exchange rates. These sources include presence of transaction costs, shipping costs, tariffs and taxes. Under linear framework, whenever there is deviation in real exchange rate from its long run mean, there arises a risk free profit opportunity through the forces of arbitrage. However, existence of such costs gives rise to a threshold or band of “no arbitrage” on both sides of real exchange rate. If the observed rate crosses the threshold, only then arbitrage occurs, otherwise, the market will not tend to correct itself. As Taylor et al. (2001) put it, “arbitrage will be heavy once it is profitable enough to outweigh the initial fixed cost but will stop short of returning the real rate to the PPP level because of the proportional arbitrage costs” (p.1018). Nonlinearity in real exchange rates may also arise from the perceived shipping time following a profitable deviation (Coleman, 1995). Cerrato and Sarantis (2006) cite other causes of nonlinearity in real exchange rates, namely, diversity in agents’ beliefs and heterogeneity in investors’ objectives. Altogether, one can expect that the greater is the deviation in real exchange rates from its long rum equilibrium level, the tendency of mean–reversion in it will be more evident. Subsequently, researchers have leaned towards nonlinear analysis of real exchange rates.

There have been many studies that looked into the time series properties of real exchange rates assuming nonlinearity in the data generating process. Michael *et al.* (1997), Sarantis (1999), Baum *et al.* (2001), Taylor *et al.* (2001) are some examples. In all of them, the authors model the presence of nonlinearity in real exchange rates. Sarno (2000a) models nonlinear exchange rates dynamics of Turkey and Sarno (2000b) does it for some Middle Eastern countries. Sollis *et al.* (2002) applied a new nonlinear unit root test, developed in their own paper, to 17 OECD real exchange rates and found the evidence of nonlinear mean reversion in 6 of them. On the other hand, Kapetanios *et al.* (2003) employ their version of nonlinear tests to detect nonlinear mean reversion in few industrial economies.

A few papers have extended this line of research to real exchange rates of Asian countries. Liew *et al*. (2004) investigated the stationarity of 11 Asian real exchange rate series but, were able to reject the unit root null using the nonlinear testing procedure and were unable to reject the null of nonstationarity by applying the augmented Dickey–Fuller (ADF) test. Wu et al. (2004) uses the panel unit root test that allows for a one-time structural break to test nonstationarity of the real exchange rates of the Pacific Rim. Their findings reject the random walk null and provide support in favor of long run purchasing power parity (PPP). Chowdhury, (2004) apply the linearity tests developed by Luukkonen et al. (1988) and Saikkonen and Luukonen (1988) and found evidence in favor of nonlinearity exhibited in the real exchange rates of Bangladesh. Ahmad and Rashid (2008) looks into the issue of stationarity of four South Asian countries (the same as the countries of this study) and China. They conclude that using the nonlinear KSS unit root tests provide more evidence in favor of stationary real exchange rates than linear unit root tests, e.g. ADF or KPSS. Other studies that document evidence of nonlinear exchange rate dynamics in the Asian countries include Liew *et al*. (2003, 2004), Liew (2004) and Zhou (2008). Using the nonlinear unit root tests, this paper finds that the real exchange rates of India, Pakistan and Sri Lanka seem to be conclusively nonstationary, while tests produce mixed results for Bangladesh.

This study differs from other similar studies. First, not many studies investigated the time series properties of South Asian real exchange rates. In fact, there are only a handful papers available so far that involve data from South Asian countries. This paper fills the vacuum and enriches the relevant literature. Second, this paper uses long span data of 35 years for all the four countries under investigation which is longer than many other studies. For example, Chowdhury (2004) applies nonlinear unit root tests on Bangladesh real exchange rates that span the period between 1994 and 2002, only 8 years of data. Such a short span of data is not sufficient to capture the long run mean reversion in the data. On the other hand, this paper uses long span data of 35 years for all the four countries under investigation. Shiller and Perron (1985) note that the poor power of univariate unit root tests cannot be overcome by simply using more frequently sampled data, for example, using monthly rather than quarterly data. Instead, if the PPP deviations die out at a very slow rate (Rogoff, 1996), researchers need to use long span rather than high frequency data sets in order to be able to detect the mean reversion in the data. The reminder of the paper is organized as follows. Section 2 discusses data and methodology used in the paper. Section 3 presents results and findings and section 4 concludes the paper.

DATA AND METHODOLOGY

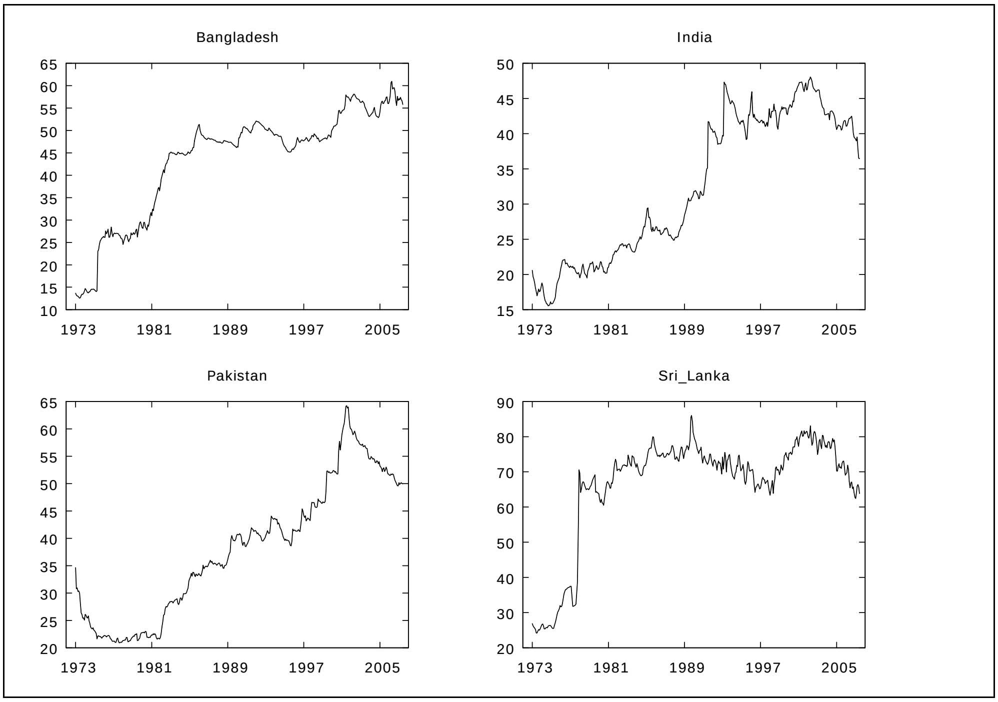
The Data

The data are of monthly frequency and span from February 1973 to June 2007, a total of 413 observations for each of the four countries. The real exchange rate is constructed using the formula: $y_t = s_t + p^* - p$, where, y_t is the real exchange rate, s_t is the nominal exchange rate, p^* and p are the foreign and domestic price indices (here, the Consumer Price Index), respectively. The data on real exchange rates have been collected from the *International Financial Statistics* of International Monetary Fund (IMF). Franses and

Dijk (2006) point out that empirical failure of PPP may be due to presence of non–traded goods in the price indices that are mostly used in PPP equations. Given the fact that “PPP is supposed to be maintained by international commodity arbitrage, it follows immediately that this applies to traded goods only” (p. 20). They develop a simple test for PPP using traded goods only and study its small sample properties. They apply the test on the post-Bretton Woods data of bilateral real exchange rates based on traded goods only in a panel of 13 industrialised countries. The study, however, reports poor evidence in support of PPP in their panel. In the current study, we use CPI because of unavailability of data on price indices based on tradable goods only for the countries of our panel. This should not undermine the findings of the paper as Franses and Dijk (2006) note that the findings based on traded goods only are mixed. On the other hand, Rogers and Jenkins (1995) and Engel (1999) suggest that the Harrod– Balassa–Samuelson (HBS) effect may not a major reason why PPP has failed to gain empirical support.

The time–plots of all four series are shown in Figure 1. We choose to look into these four countries for two reasons. First, these countries have exchange rate arrangements that can be characterized as either free–floating or managed floating. Other countries in the South Asian region, e.g. Nepal, Maldives and Bhutan, maintain *de facto* pegged exchange rate arrangements. Second, the countries of our interest are the largest four economies in this region, while the three other countries are rather small in size.

FIGURE 1. SOUTH ASIAN REAL EXCHANGE RATES



The KSS Test

Kapetanios, Shin, and Snell (2003) (hereafter, the KSS) broaden the much–familiar augmented Dickey–Fuller (ADF) test to detect nonstationarity in a time series. They keep the null hypothesis of nonstationarity as in the ADF test, but the alternative hypothesis is now that the series is nonlinear but globally stationary process. In order to understand the basis of the new nonlinear unit root test, known as the KSS test, we consider a model for univariate exponential smooth transition autoregressive of order 1, ESTAR(1) given as follows:

$$y_t = y_{t-1} + \gamma\, y_{t-1}[1-\exp(-\theta y_{t-1}^2)] + \varepsilon_t \quad , \quad t = 1,\ldots\ldots, T \tag{1}$$

where, $\varepsilon_t \sim i.i.d.(0,\sigma^2)$. Equivalently, the above equation can be rewritten as follows,

$$y_t = \{1+\gamma[1-\exp(-\theta y_{t-1}^2)]\} y_{t-1} + \varepsilon_t \tag{2}$$

Kapetanios, Shin, and Snell (2003) transformed equation (2) as follows,

$$\Delta y_t = \gamma\, y_{t-1}[1-\exp(-\theta y_{t-1}^2)] + \varepsilon_t \tag{3}$$

where, y_t is the de-trended and/or de-meaned series of interest and $[1-\exp(-\theta y_{t-1}^2)]$ is the exponential transitional function in the KSS test to portray the nonlinear adjustment. The null hypothesis of the KSS test is that $H_0 : \theta = 0$ against the alternative of $H_1 : \theta > 0$. However, because γ is not directly identifiable under the null, it becomes impossible to test the null hypothesis. Therefore, Kapetanios, *et al.* (2003) reparameterize the Equation (3) through a first–order Taylor series approximation and obtained the following auxiliary regression

$$\Delta y_t = \delta\, y_{t-1}^3 + \varepsilon_t \tag{4}$$

In order to take into account possible presence of serial correlation in the error terms, Equation (4) can be extended as follows,

$$\Delta y_t = \delta\, y_{t-1}^3 + \sum_{k=1}^{q} \rho\, \Delta y_{t-k} + \varepsilon_t \tag{5}$$

where, q is the number of augmentations that can be specified using any standard lag length selection criteria. The null hypothesis is now that $H_0 : \delta = 0$ against the alternative of $H_1 : \delta < 0$. Kapetanios, *et al.* (2003) recognize that the test statistic does not have an asymptotic standard normal distribution and therefore, provide the critical values on p. 364 of their article. For the convenience of the reader, we reproduce the critical values below in Table 1.

TABLE 1. ASYMPTOTIC CRITICAL VALUES FOR THE KSS TEST

Significance level	Case 1	Case 2	Case 3
1%	–2.82	–3.48	–3.93
5%	–2.22	–2.93	–3.40
10%	–1.92	–2.66	–3.13

Notes: Case 1, Case 2 and Case 3 refer to the underlying model with the raw data, the demeaned data and the detrended data, respectively. These values apply for both serially uncorrelated and correlated cases. The critical values are reproduced from Kapetanios *et al. (2003, p. 364).*

RESULTS AND FINDINGS

Table 2 reports results of the ADF and the KPSS tests. In order to capture different possibilities in the data generating process, we apply variants of these tests, namely, with constants and with constants and trend terms in the test equations. The difference between the ADF and the KPSS test is that while the former obtains the test statistic under the null of nonstationarity, the latter assumes the null of stationarity to run the test. As for the ADF test, one can not reject the null hypothesis in all cases at hand. On the other hand, the KPSS test rejects the null hypothesis of stationarity in all cases confirming the results of the ADF tests. Together these results indicate that the real exchange rates of South Asian countries are nonstationary and have no long run mean to revert to.

TABLE 2. LINEAR UNIT ROOT TEST RESULTS

	ADF Test		KPSS Test	
	Constant	Constant and Trend	Constant	Constant and Trend
Bangladesh	–2.638 (1)	–1.969 (1)	5.449* (5)	1.101* (5)
India	–1.287 (1)	–0.980 (1)	6.434* (5)	0.310* (5)
Pakistan	–0.852 (8)	–2.221 (8)	6.493* (5)	0.677* (5)
Sri Lanka	–2.861 (7)	–1.959 (7)	3.208* (5)	1.219* (5)

Notes: For the ADF test, lag lengths are given next to test statistics within parentheses which are selected using testing down method from a maximum lag of 8. For the KPSS test, the lag truncation parameter equals the integer part of $4(T/100)^{1/4}$. (*) *denotes rejection of stationarity null at 1% level of significance. The 1% critical value for the null of level stationarity is 0.739 and trend stationarity is 0.216.*

Table 3 presents results of the KSS test that allows for nonlinear mean reversion in the data generating process. The KSS test assumes that the data are nonstationary under the null against a nonlinear but globally stationary process. Three different versions of the KSS test are applied, as suggested in Kapetanios *et al.* (2003), namely, using the raw series, the demeaned series and detrended series. The lag length is fixed at q = 8 following Liew *et al.* (2004) and Zhou (2008). The results reveal that we can reject the null of nonstationarity only in six out of 24 cases. More specifically, only for the Bangladeshi real exchange rates we find evidence of nonlinear mean reversion in half of the cases. On the other hand, tests on Pakistan and Sri Lanka real exchange rates can reject the null in only one and two cases respectively. For the real exchange rates, the test can not reject the null in any case. Overall, there is more evidence in favor of nonstationarity in major South Asian real exchange rates except for Bangladesh.

TABLE 3. THE KSS TEST RESULTS

	Raw Data		**Demeaned Data**		**Detrended Data**	
	KSS_A	**KSS_{NA}**	**KSS_A**	**KSS_{NA}**	**KSS_A**	**KSS_{NA}**
Bangladesh	–2.580*	–2.729**	–2.863***	–2.223	–3.043	–2.347
India	–1.808	–1.576	–1.655	–1.296	–1.369	–0.664
Pakistan	–1.302	–0.492	–1.491	–0.798	–2.117	–5.468*
Sri Lanka	–3.479*	–3.189*	–1.417	–1.081	–1.505	–1.243

Notes: Lag is fixed at q = 8 following the existing literature. *, **, *** *denotes rejection at 1% 5% and 10%, respectively. The subscript A and NA stand for augmented to take serial correlation in the data and not–augmented, respectively.*

CONCLUDING REMARKS

The paper aims to investigate stationarity of real exchange rates of four major South Asian countries, namely, Bangladesh, India, Pakistan and Sri Lanka. To this aim, we apply the KSS test developed by Kapetanios et al. (2003). Unlike most commonly used unit root tests, like the ADF and KPSS tests, the KSS test assumes that real exchange rates are nonlinear process rather than linear one. The KSS test statistic is calculated assuming nonstationarity under the null, while it allows for stationary but exponential smooth transition autoregressive movements in real exchange rates under the alternative hypothesis.

The findings as outlined above suggest that real exchange rates of four South Asian countries follow mostly nonstationary process except for few cases. Unit root tests that assume linearity in the real exchange rates show that all series of our interest are nonstationary. On the other hand, tests assuming nonlinearity in the real exchange rates also yield very much similar results. However, there are some notable exceptions as seen in Table 3. In general, we see that real exchange rates of India, Pakistan and Sri Lanka are all indistinguishable from $I(1)$ process. The only notable exception is real exchange rates of Bangladesh. Among different versions of the KSS test, one can reject in half of the cases for Bangladesh. As discussed earlier, our findings are in contrast with most studies that apply nonlinear unit root tests, more specifically, the KSS test.

The results have important economic implications. First, the much celebrated theory of purchasing power parity (PPP) does not hold to be valid in this region of the world. In other words, exchange rates of these countries seem to fail to adjust to changes in the relative price levels between their countries and the USA. Given the fact that the USA remains to be one of the major destination of exports of these countries, this failure of the real exchange rates to adjust to changes in the relative price levels even in the long run, may result in permanent trade imbalances (e.g. current account deficit through falling terms of trade). Although, India is also a dominant trading partner of the other three countries of the panel, unavailability of reliable data on bilateral real exchange rate makes its difficult to test for PPP vis-à-vis India. Second, as the real exchange rates are nonstationary, this may also invalidate the so–called nexus between real exchange rates and real interest differential, unless the latter is also a nonstationary process and cointegrate with the former in the long run (see Coakley *et al*. 2004, for more details on this nexus). Third, when real exchange rates are nonstationary, it is possible for arbitrageurs to make risk-free money from the goods market thereby causing macroeconomic imbalances and potential real exchange rate devaluation in South Asia (Parikh and Williams, 1998).

ENDNOTES

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