The Long-run Relationship between Real Exchange Rate and Real Interest Rate in Asian Countries: An Application of Panel Cointegration

SHAISTA ALAM, MUHAMMAD SABIHUDDIN BUTT and AZHAR IQBAL

1. INTRODUCTION

The role of exchange rate policy in economic development has been the subject of much debate and controversy in the development literature. Interest rates and exchange rates are usually viewed as important in the transmission of monetary impulses to the real economy. In the short run the standard view of academics and policy-makers is that a monetary expansion lowers the interest rate and rises the exchange rate, with these price changes then affecting the level and composition of aggregate demand. Frequently, these influences are described as the liquidity effects of monetary expansion, viewed as the joint effect of providing larger quantities of money to the private sector. Popular theories of exchange-rate determination also predict a link between real exchange rates and real interest rate differentials. These theories combine the uncovered interest parity relationship with the assumption that the real exchange rate deviates from its long-run level only temporarily. Under these assumptions, shocks to the real exchange rate—which are often viewed as caused by shocks to monetary policy—are expected to reverse themselves over time. This study investigates the long-run relationship between real exchange rates and real interest rate differentials using recently developed panel cointegration technique. Although this kind of relationship has been studied by a number of researchers,[1] very little evidence in support of the relationship has been reported in the case of developing countries. For example, Meese and Rogoff (1988) and Edison and Pauls (1993), among others, used the Engle-Granger cointegration method and fail to establish a clear long-run relationship in their analysis. Somewhat stronger evidence

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Shaista Alam and Azhar Iqbal are both Project Economist and Muhammad Sabihuddin Butt is Senior Research Economist at the Applied Economics Research Centre, University of Karachi.

[1]See MacDonald (2000), for a survey.

has been reported by Edison and Melick (1999) and MacDonald (1997) using Johansen's cointegration technique.

The real exchange rate has received increasing attention as a critical relative price. Realignment of an overvalued real exchange rate has been one of the critical components of adjustment programmes supported by the World Bank [Thomas, *et al.* (1990); Conway (1991)]. This increased attention has stimulated research into has impact of exchange rate policy on overall economic performance. Several recent papers have shown an empirical association between real exchange rate variability and various indicators of economic performance output growth [Cottani, Canallo and Khan (1990); Dollar (1990); and Lopez (1991)], export performance [Corbo and Caballero (1990)], and investment [Serven and Solimano (1991); Faine and deMelo (1990)]. The developed countries have moved, since the collapse of the Bretton Woods arrangements in 1973, towards a policy of more or less freely floating exchange rates, at least across major currency areas. On the other hand, nearly all developing countries actively control the nominal exchange rate. Exchange rates are generally pegged to a currency, or composite of currencies. The frequency of revision of the exchange rate peg varies, with countries pursuing a managed float revising frequently, while other countries adjust annually or less. In the classical discussion the equilibrium real exchange rate was shown to be invariant to the choice of fixed or floating nominal exchange rates. The question was simply whether nominal exchange rates or national price levels, through the money supply, should adjust to reach equilibrium. As a matter of historical practice allowing the domestic price levels to rise more slowly than international prices has not been widely observed in LDCs. In developing countries faced with an appreciated RER the common pattern has been to "defend" overvalued exchange rates and resist nominal devaluations. Governments try to staunch the incipient current account deficit generated by overvaluation imposing increasingly severe restrictions on both the capital and current account payments while simultaneously attempting to mitigate the effects of overvaluation on marginal exporters. This disequilibrium process often ends in a crisis, with a massive jump in the nominal rate aimed at reestablishing a manageable RER.[2] Krueger (1978), provides an detailed account of this pattern in the 1970s for a number of LDCs.

The general view of the economics profession as represented in Meese (1990) is that past research has been unsuccessful in explaining exchange rate movements. Many earlier papers which model exchange rate movements as a function of real interest rate differentials and other economic fundamentals, have obtained statistically significant coefficients on real interest rate differentials [Frankel (1979); Hooper and Morton (1982); Shafer and Loopesko (1983) and Boughton (1987)]. However, more recent work that uses more sophisticated empirical techniques

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[2]As early as 1967, prior to floating rates, Kindleberger characterised the combination of overvalued rates with current and capital account restrictions as a "disequilibrium system".

generally has been unable to establish a long-run relationship between these variables. Two of the more well-known papers are those of Campbell and Clarida (1987) and Meese and Rogoff (1988). Campbell and Clarida examine whether real exchange rate movements can be explained by shifts in real interest rate differentials and find that expected real interest rate differentials have simply not been persistent enough, and their innovation variance not large enough, to account for much of the fluctuation in the dollar's real exchange rate. Meese and Rogoff test for cointegration and find that they cannot reject the null hypothesis of non-cointegration between real long-term interest rate differentials and real exchange rates. They suggest that this finding may indicate that a variable omitted from the relationship, possibly the expected value of some future real exchange rate, may have a large variance which, if included, would lead to finding cointegration. This conjecture of an important missing variable is also consistent with the Campbell-Clarida results. Two recent papers by Coughlin and Koedijk (1990) and Blundell-Wignall and Browne (1991), however, find that real exchange rates and real interest rates may be cointegrated. The ability of Blundell-Wignall and Browne to find cointegration is due to the inclusion of the difference in the share of the cumulated current account relative to GNP in the relevant countries; the finding of cointegration by Coughlin and Koedijk is only for the mark/dollar exchange rate and results from extending the sample period by using more recent data.

This paper provides perhaps the strongest evidence yet in favour of the real exchange rate—real interest rate differentials model first time in the case of Asian developing countries, including Pakistan. Our success in establishing clear long-run relationships is attributable to the use of panel cointegration technique. We begin by examining the statistical properties of the data. Using a panel unit root test, we cannot reject the null hypothesis of unit root for real exchange rate and real interest rate differential. We then test the long-run implications of the model for the cointegration of real exchange rates and real interest rates. We have detected the long-run relationship between real exchange rates and real interest rates using Johanson-cointegration and Panel cointegration tests over the entire sample period for the countries located in South Asia and South-East Asia. The rest of the paper is organised as follows. Section 2 discusses the theoretical relationship between real exchange rate and real interest rate differentials, and Section 3 examines the data and the time series properties of data. Section 4 discusses the empirical results of Johansen (Max and Trace) cointegration and panel Unit Root and panel cointegration for the panel of ten Asian countries and Section 5 concludes.

2. THE REAL EXCHANGE RATE—REAL INTEREST RATE RELATIONSHIP

The most common way of deriving the real exchange rate—real interest rate (RERI) relationship, which we refer to as the traditional derivation, is to exploit the

Fisher parity condition (1), a real exchange rate identity (2), and the uncovered interest rate parity condition (UIP) (3):

$$\pi_{it} = r_{it} + E_t \Delta P_{it+1}, \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (1)$$

$$S_{it} \equiv P_{it} - P^*_{it} + REX_{it}, \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (2)$$

$$E_t \Delta S_{it+1} = \pi_{it} - \pi^*_{it} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (3)$$

Where, S_{it} is the log of the nominal exchange rate (home currency price of a unit of foreign currency) for country i at time t ($i=1,2,\dots\dots N$ and $t=1,2,\dots\dots T$), REX_{it} is the log of the real exchange rate, P_{it} is the log of the price level, π_{it} is the nominal interest rate, r_{it} is the real interest rate, and $E_t \Delta P_{it+1}$ is expected inflation. An asterisk denotes a foreign variable, Δ is the first difference operator, and $E_t(.it+1)$ implies the expected value of (.) for time $t+1$, formed at time t using all relevant information. The Fisher parity condition (1) is also assumed to hold in the foreign country. The RERI relationship may then be derived using the expected version of Equation (2)

$$E_t S_{it+1} = E_t REX_{it+1} + E_t P_{it+1} - E_t P^*_{it+1} \quad \dots \quad \dots \quad \dots \quad \dots \quad (4)$$

combining Equation (4) with Equations (1) and (3):

$$REX_{it} = E_t REX_{it+1} - (r_{it} - r^*_{it}) \quad \dots \quad \dots \quad \dots \quad \dots \quad (5)$$

The above equation indicates that the current real exchange rate can be explained by the expected future real exchange rate and the real interest rate differential (RID). The latter is assumed to be negatively correlated with the real exchange rate, as in classic Dornbusch (1976) model. Since the expected real exchange rate is unobservable, it is assumed here to be constant over time and this is consistent with the Dornbusch model. However, we attempt to increase the power of our test over existing studies that exploit this assumption by letting the expected rate vary across individual countries—that is:

$$E_t REX_{it+1} = \alpha_i \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (6)$$

If $r_{it} - r^*_{it} = RID_{it}$

Then, our econometric analysis is based on the following equation:

$$REX_{it} = \alpha_i + \beta_i(RID_{it}) + u_{it} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (7)$$

Where α_i captures the fixed effect specific to country i, and the residual term is expressed as u_{it}. The term β_i is the vector of parameters and is written here to allow for a heterogeneous relationship between the real exchange rate and the real interest rate differential (Although in our assessment of the size of β_i, we impose a homogeneity restriction on this parameter). The estimated value of β_i is expected to

be negative as shown in Equation (5). Finally, for operational reasons, we impose a symmetry restriction on the interest rates.

In the context of the above derivation of the RERI, Edison and Melick (1999) have demonstrated that the expected size of β_i will be positively proportional to the maturity of the bonds underpinning the interest rates. The absolute values of the coefficients on long-term real interest rate differentials (RLID) should be greater than those of short-term real interest rate differentials (RSID). In contrast, however, the size of the constant α_i, may be model and country specific, since there is no particular economic theory to predict the expected level of real exchange rate.

3. THE DATA

The data are obtained from International Financial Statistics of the International Monetary Fund, World Development Indicator CD-Rom and Country Years Book. The issues in this paper are fundamentally empirical. Before presenting a formal model, we consider the data by visually inspecting it. In particular, we want to know whether the results are conditional on: (i) the time period selected, (ii) the inflation measure used to construct the real interest rate, and (iii) the choice of exchange rate. Some of the differences in the results in the existing literature appear to stem from aspects of the data selected. It is possible for graphs to portray the data misleadingly, nevertheless we think this method is useful to highlight the above issues.[3]

The annual data cover the 1971–2000 period for 10 Asian countries (Bangladesh, India, Indonesia, Korea, Malaysia, Pakistan, Philippine, Singapore, Sri Lanka and Thailand). The exchange rates are bilateral rates against the U.S. dollar, designating the United States as the "Foreign Country" in our study. Both long- and short-term nominal interest rates are used to construct the real interest rate through Equation (1). Long-term interest rate measured as the yields on government bonds for the 10 Asian countries.[4] Short-term interest rate measured as money market rate/Treasury bill rate. The consumer price index (CPI) is the price measure used to calculate inflation, and expected inflation is calculated using one-sided moving average (MA) filter consisting of four year lag of actual inflation [see, for example, Edison and Pauls (1993)].

Figure 1 presents the case of Thailand. The relationship between real exchange rate (TREX) and real short run interest rate differential (TRSID) using a four year central moving average measure of expected inflation. A strong relationship is seen over most of the period. In Figure 2, there appears to be little relationship between the real exchange rate and real long-run interest rate differential

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[3]Danker and Hooper (1990) also present several graphs in their examination of this relationship.

[4]In most of the 10 countries, the liberalisation of financial markets is a fairly recent phenomenon. Previously, ten-years bonds did not exist in many of these countries. For the early part of our sample, we used the best available proxy—often an average yield on a set of bonds of intermediate maturity.

(TRLID) as compare to Figure 1. Figures 3 and 4 plot for Sri Lanka. In case of real exchange rate (SREX) and real short-run interest rate differential (SRSID) relationship is more clear than SREX and real long-run interest rate differential (SRLID) in most of the period. Figures 5 and 6 show the relationship between real exchange rate and real interest rate differential of Singapore. Figure 5 indicates that movement in the real exchange rate (SIREX) and real short-run interest rate differential (SIRSID) is roughly correlated over most of the period. The decline in the exchange rate during the early 1970s is consistent with a general uptrend in the interest differential. The relationship also holds up reasonably well during the whole period of time.

A different story about the relationship between real long-run interest rate differential (SIRLID) and real exchange rate (SIREX) emerges in Figure 6 where interest rate differential and real exchange rate decline simultaneously during first half of 1970s. Also graph shows that the relationship between SIREX and SIRLID does not resemble its long-term counterpart over most of the period. Figure 7 illustrates that the relationship between real exchange rate (PREX) and real short-run interest rate differential (PRSID) of Pakistan. The Chart shows a tendency for movements of real short run interest rate differential to precede movements in real exchange rate, but the strength of this relationship may vary over time. In Figure 8 the decline in real long-run interest rate differential (PRLID) is consistent with a upward trend of real exchange rate (PREX) during early part of 1970s. Also upward movement of PRLID lead to downtrend of PREX in the last part of 1970s. The relationship also holds up very well during 1990s, when the real exchange rate continued to rise strongly after the real long-run interest rate differential turned down.

Figures 9 and 10 display the relationship between real exchange rate and real interest rate differentials of Philippine. Figure 9 shows very surprising about the relationship between real exchange rate (PHREX) and real short-run interest rate differential (PHRSID), because both have same trends over most of the period of time. In Figure 10 the relationship between real exchange rate (PHREX) and real long-run interest rate differential (PHRLID) does not hold up well, in general, because of PHRLID over a short horizon tends to vary more than the value of PHREX. Figures 11 and 12 illustrate that the relationship between real exchange rate and real interest rate differentials of Malaysia. Figure 11 more or less suggest the relationship between real exchange rate (MREX) and real short-run interest rate differential (MRSID). But Figure 12 depicts, the lack of correlation between real exchange rate (MREX) and real long-run interest rate differential (MRLID). Figures 13 and 14 plot for Korea. Figure 13 shows a strong relationship between real exchange rate (KREX) and real short-run interest rate differential (KRSID) over time except the period of financial (Currency) crises 1997-98, when exchange rate moved up dramatically. Same illustration is seen from Figure 14. Figure 15 and 16
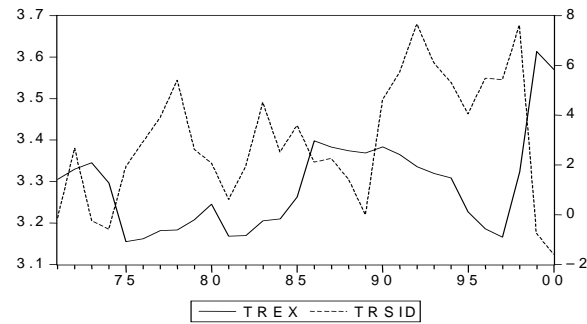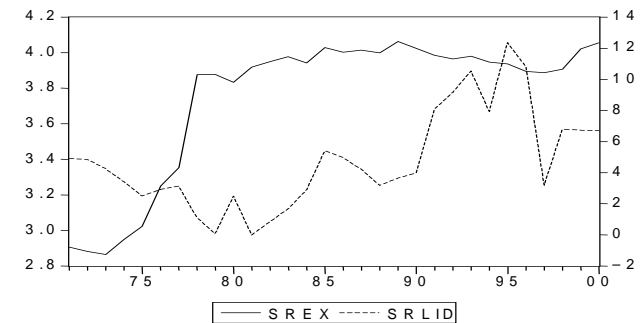
Fig. 1. Real Exchange Rate and Real Short-run Interest Rate Differential of Thailand.
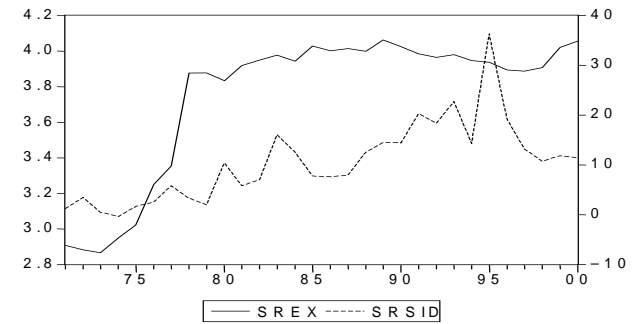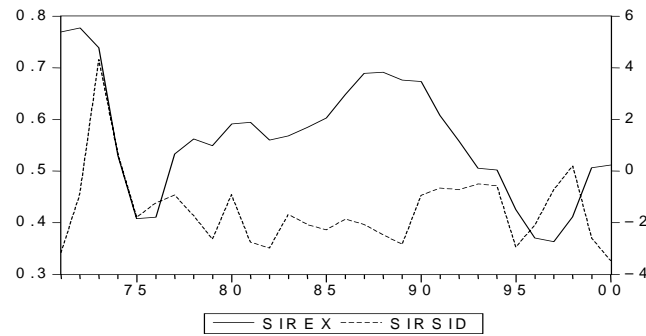

Fig. 3. Real Exchange Rate and Real Short-run Interest Rate Differential of Sri Lanka.
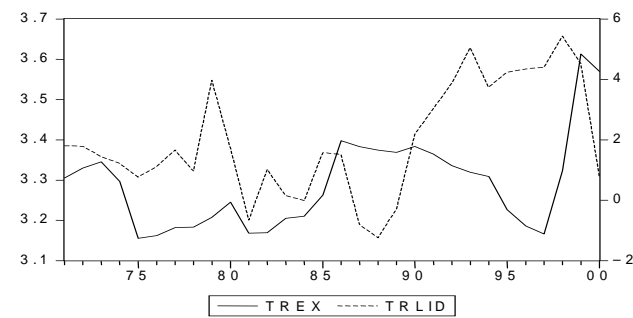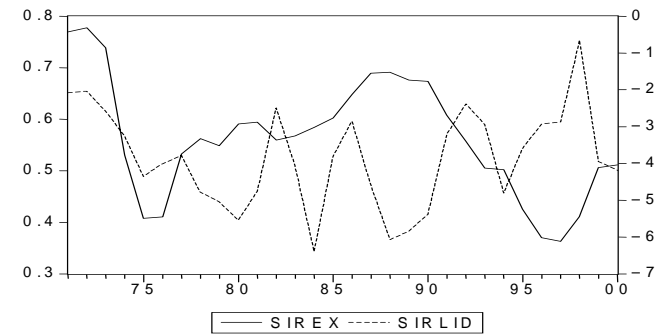

Fig. 2. Real Exchange Rate and Real Long-run Interest Rate Differential of Thailand.
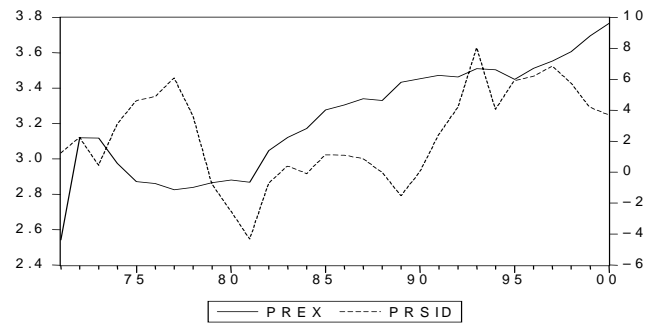

Fig. 4. Real Exchange Rate and Real Long-run Interest Rate Differential of Sri Lanka.
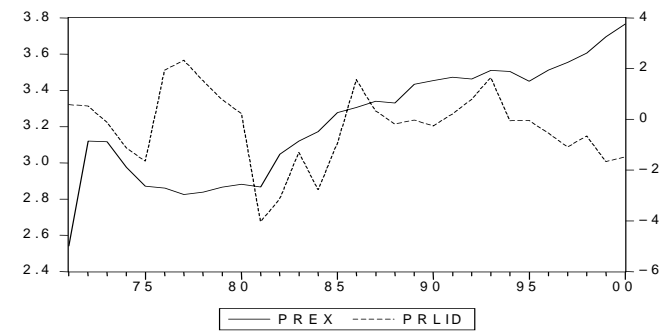
Fig. 5. Real Exchange Rate and Real Short-run Interest Rate Differential of Singapore.

Fig. 6. Real Exchange Rate and Real Long-run Interest Rate Differential of Singapore.

Fig. 7. Real Exchange Rate and Real Short-run Interest Rate Differential of Pakistan.

Fig. 8. Real Exchange Rate and Real Long-run Interest Rate Differential of Pakistan.

Fig. 9. Real Exchange Rate and Real Short-run Interest Rate Differential of Philippine.

Fig. 10. Real Exchange Rate and Real Long-run Interest Rate Differential of Philippine.

Fig. 11. Real Exchange Rate and Real Short-run Interest Rate Differential of Malaysia.

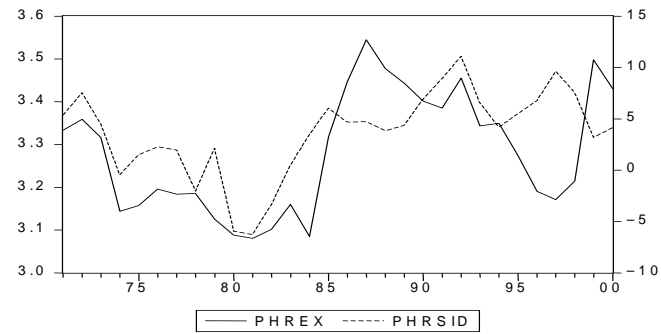**Fig. 12. Real Exchange Rate and Real Long-run Interest Rate Differential of Malaysia.**

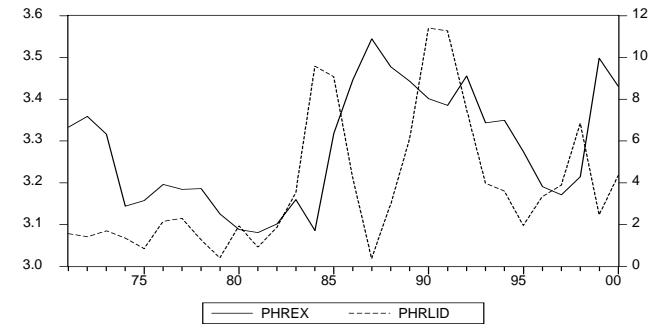**Fig. 13. Real Exchange Rate and Real Short-run Interest Rate Differential of Korea**.

Fig. 14. Real Exchange Rate and Real Long-run Interest Rate Differential of Korea.
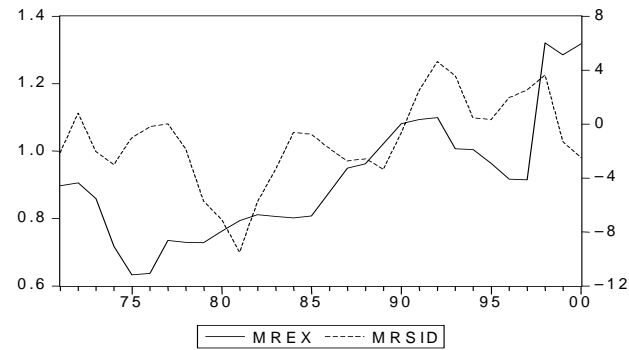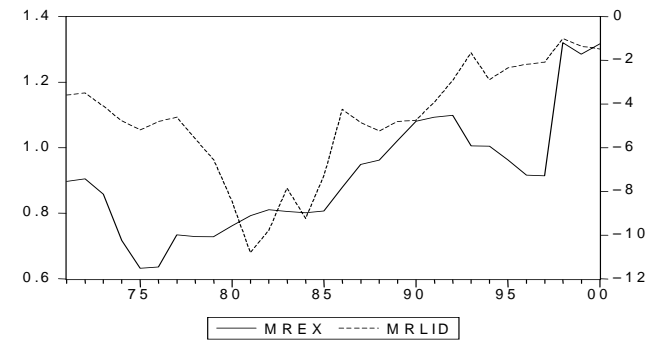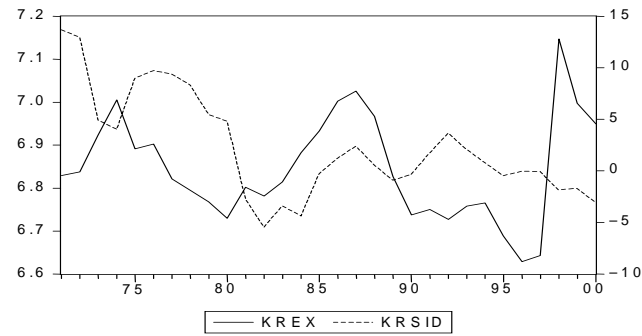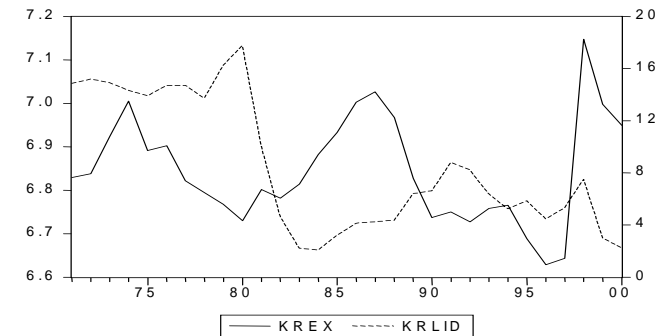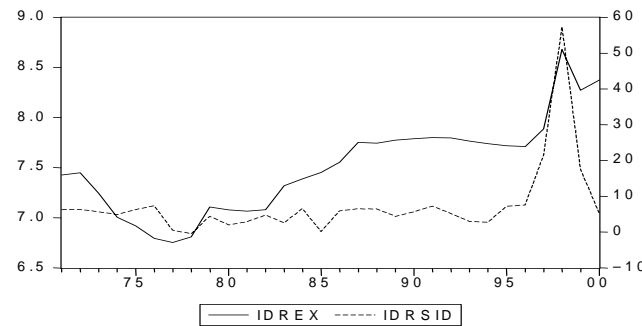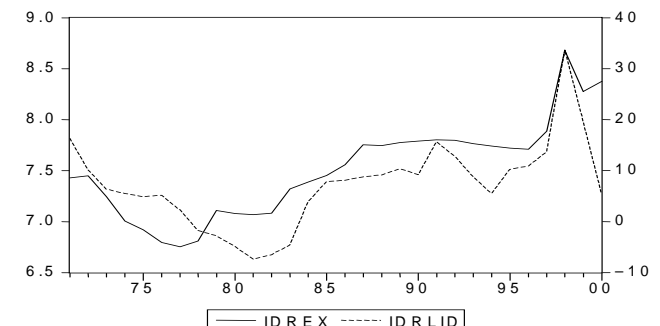

Fig. 15. Real Exchange Rate and Real Short-run Interest Rate Differential of Indonesia.
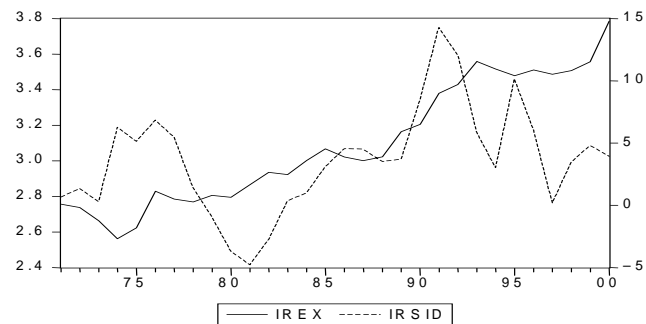

Fig. 16. Real Exchange Rate and Real Long-run Interest Rate Differential of Indonesia.

display the relationship between real exchange rate and real interest rate differentials of Indonesia. But there is no clear relationship between real exchange rate (IDREX) and real short-run interest rate differential (IDRSID) in Figure 15. In Figure 16 there is a correlation between IDREX and real long-run interest rate differential (IDRLID).

Figures 17 and 18 show the relationship between real exchange rate (IREX) and real interest rate differential (IRID) of India. The picture illustrate a strong relationship between IREX and IRID. In Figure 19 real short-run interest rate differential of Bangladesh (BRSID) has changed vary rapidly as compare to real exchange rate (BREX). So no clear evidence in support of our hypothesis. Figure 20 also shows no correlation between BREX and real long-run interest rate differential (BRLID). All in all, most of these graphs seem to suggest that the strong relationship between real exchange rate and real interest rate differentials.

Our data set requires a cautionary note. In a cross-country study such as ours, there is inevitably a trade-off between data availability and data comparability. In order to maximise the power of Panel Cointegration test, we have opted for the widest group of currencies. This inevitably means that our data are not exactly comparable across countries. The comparability of price series in panel studies is well known. [See, for example, Frankel and Rose (1996)]. In our study, however, this is compounded by country comparability issues relating to the interest rates. Although our short-term interest rates are reasonably comparable across countries (the majority being money market rates), this is not the case for our long-term interest rates, which vary in maturity from three to ten years. To obtain consistent maturity yields across countries would greatly reduce the cross-sectional dimensions of our data set and we have not adopted that strategy here. But we are encouraged by the study of Flood and Taylor (1996), who use a heterogeneous set of medium term interest rates to test UIP hypothesis in a panel setting and are unable to reject the hypothesis.

We analyse orders of integration of the data using Augmented Dickey-Fuller (ADF) test, a standard unit root test. The ADF statistics are calculated with a constant and a constant plus a time trend, respectively. These tests have a null hypothesis of non-stationarity against an alternative of stationarity (around a constant or a constant and trend). In all of these tests, we started with a lag length of five, and sequentially deleted insignificant lags until the last lag was significant. The results are reported in Table 1 for both levels and differences of the series and indicate that the real exchange rates are clearly I(1) processes. The results with respect to the real interest rate differentials are also I(1), thereby implying that there may be long-run relationship of the form (5).

Fig. 17. Real Exchange Rate and Real Short-run Interest Rate Differential of India.
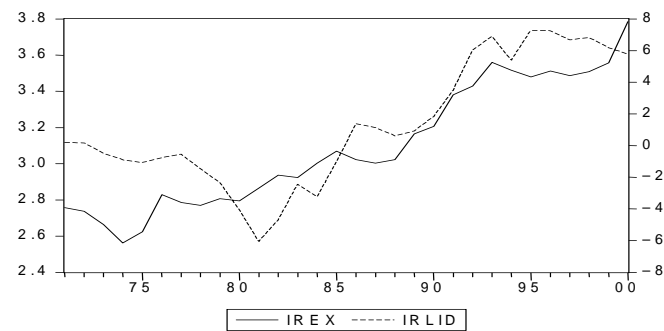
Fig. 18. Real Exchange Rate and Real Long-run Interest Rate Differential of India.
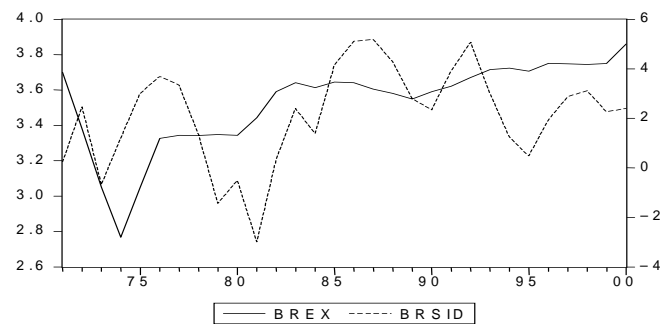
Fig. 19. Real Exchange Rate and Real Short-run Interest Rate Differential of Bangladesh.

Fig. 20. Real Exchange Rate and Real Long-run Interest Rate Differential of Bangladesh.

Table 1

Unit Root Test[a]

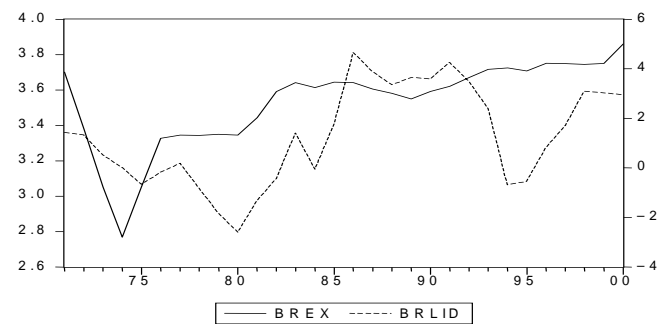|	Real Exchange Rate		Real Long-run Interest Rate Differential		Real Short-run Interest Rate Differential	
	Constant	Constant and Trend	Constant	Constant and Trend	Constant	Constant and Trend
(a) Level						
Bangladesh	–2.208	–2.073	–1.972	–2.559	–2.485	–2.675
India	0.453	–1.893	–0.813	–2.223	–2.582	–2.708
Indonesia	–0.202	–2.462	–2.321	–2.997	–0.508	–1.732
Korea	–2.498	–2.654	–1.718	–2.48	–2.283	–3.086
Malaysia	–0.529	–3.089	–1.19	–2.143	–1.424	–2.662
Pakistan	0.723	–2.727	–1.816	–3.017	–1.982	–2.222
Philippine	–2.006	–2.528	–1.181	–0.750	–2.142	–3.122
Singapore	–1.161	–1.778	–1.182	–1.906	–2.335	–2.460
Sri Lanka	–2.489	–1.675	–1.546	–2.56	–1.652	–2.164
Thailand	–1.199	–2.321	–2.166	–2.481	–2.348	–2.315
(b) Differences						
Bangladesh	–5.591*	–5.401*	–3.784*	–3.705**	–3.917*	–3.868**
India	–3.514**	–3.622***	–3.589**	–3.57**	–4.476*	–4.909*
Indonesia	–3.60**	–3.809**	–4.112*	–3.965**	–5.645*	–6.011*
Korea	–4.156*	–4.173**	–3.826*	–3.765**	–4.614*	–4.376*
Malaysia	–3.558**	–3.868**	–3.967*	–4.235**	–3.559**	–3.432***
Pakistan	–4.128*	–4.351*	–4.767*	–4.672*	–3.162**	–4.776*
Philippines	–3.14**	–4.955*	–4.215*	–4.127**	–4.037*	–3.959*
Singapore	–3.981*	–3.925**	–5.936*	–6.038*	–9.40*	–9.484*
Sri Lanka	–5.383*	–5.261*	–4.924*	–4.849*	–4.992*	–5.034*
Thailand	–4.250*	–4.381*	–4.236*	–4.028**	–3.109**	–5.082*

[a]The Augmented Dickey-Fuller test is implemented to test the Null hypothesis that the series in equation is I(1) in the columns under "Level" or I(2) in the columns under "Differences". The critical values are obtained from MackKinon (1991). The full sample is used for calculations.

 * Statistics that are significant at 1 percent level.
 ** Statistics that are significant at 5 percent level.
 *** Statistics that are significant at 10 percent level.

3.1. Time Series Properties of Data: Testing for Non-stationarity and Cointegration in Panel Data

In this section we summarise the non-stationary panel data tests for unit roots and cointegration we will be using and offer some intuition behind the testing. The test of null hypothesis of cointegration states that under the:

H_o = There exists a long-run relationship between real exchange rate and real interest rate differentials.

The model allows for varying intercepts, Trends and varying slopes and thus a cointegration test for heterogeneous cross-sections is applicable. An intuitive interpretation of the null hypothesis would be that if there exists a long-run

relationship between these two variables then real interest rate differential is reasonable and helpful in describing real exchange rate in the long run:

The first step is determining a potentially cointegrated relationship is to test whether the variables involved are stationery or non-stationary, i.e. whether the individual series contain unit root. If all the variables are stationary, then traditional estimation methods can be used to estimate the relationship between the variables, in this case REX, RLID and RSID. If, however, at least one of the series (REX and RLID or RSID) is determined to be non-stationary then more care is required.

The test we use for stationarity was first presented by Im *et al.* (1997). In their paper, Im, Pesaran and Shin (IPS) present a statistic testing the H_o of non-stationarity for a variable observed in a panel. The statistic is based on the Augmented Dickey-Fuller (ADF) test widely used in time series literature. Recall that the ADF test in the time series case can be written in panel data,

$$\text{Drift model}: \quad \Delta Y_{i,t} = \alpha_i + \rho_i Y_{i,t-1} + \sum_{j=1}^{p} \gamma_{ij} \Delta Y_{it-j} + \text{residual} \qquad \dots \quad (8)$$

$$\text{Trend model}: \quad \Delta Y_{i,t} = \alpha_i + \delta_i t + \rho_i Y_{,it-1} + \sum_{j=1}^{p} \gamma_{ij} \Delta Y_{i,t-j} + \text{residual} \quad \dots \quad (9)$$

where,

$$P = 0, 1, 2$$

Assuming that the cross sections are independent, IPS propose that the best way to combine information is to average the individual ADF *t*-statistics and use the following properties on mean:

$$\psi_{\bar{t}} = \frac{\sqrt{N}\,(\bar{t}_{N,T} - E[\bar{t}_{N,T}(P,O)])}{\sqrt{Var\,(\bar{t}_{N,T})}} \Rightarrow N(0,1) \qquad \dots \qquad \dots \qquad \dots \quad (10)$$

where, $\Rightarrow$ denotes convergence in distribution $\bar{t}_{N,T} = \dfrac{1}{N}\sum_{i=1}^{N} t_i$, t_i is the t-statistic for

the estimate of ρ_i in (8) and (9), and $E[\bar{t}_{N,T}(P,o)]$ is taken under the null hypothesis $\rho_i{=}0$ for all *i* and with choice $P = (P_1, P_2....., P_i......P_N)'$ of the lag-length vector for the regressions unit by unit in (8, 9). Ψ_t can be compared to critical values for one-sided $N(0,1)$ distribution. The moments of $\bar{t}_{N,T}$ depend on the number of time series observations and appropriate lag order, P_i, for each cross-section.

If we find that REX and RLID (RSID) one or both of the variables are non-stationary, then we can test the system for cointegration. The residual-based test for panel cointegration we use comes from McCoskey and Kao (1998). The test is constructed from the partial sums of the estimated residuals for a regression equation

of non-stationary variables. It is a panel data version of the LM-Statistic proposed by Harris and Inder (1994). The precise form of the test is given:

$$\overline{LM} = \frac{1}{N} \sum_{i=1}^{N} \left(\frac{1}{(T)^2} \frac{\sum_{t=1}^{T} S_{it}^{+2}}{\hat{\overline{W}}_{1.2}^2} \right) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

where,

$$\hat{\overline{W}}_{1.2}^2 \text{ is a consistent estimator of } \overline{W}_{1.2}^2 = \overline{W}_1^2 - \overline{W}_{12}\Omega_{22}^{-1}\overline{W}_{21}$$

$$Y_{i,k}^+ = Y_{iK} - \hat{\overline{W}}_{12}\hat{\Omega}_{22}^{-1}W_{i,k}$$

and

$$S_{it}^+ = \sum_{K=1}^{t} (Y_{i,K}^+ - \alpha_i - \hat{\beta}_i^{+\prime} X_{i,k})$$

$\hat{\beta}_i^+$ is the fully modified estimator (FM) of β_i.

It can be shown that, for example, McCoskey and Kao (1998):

$$LM^* = \frac{\sqrt{N}(\overline{LM} - \mu_v)}{\sqrt{\sigma_v^2}} \Rightarrow N(0,1) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (12)$$

Where,

$\mu_v = E[\int v^2]$, $\sigma_v^2 = Var[\int v^2]$ and $\int v^2$ is defined in McCoskey and Kao (1998). The test is one sided: $N(0,1)$ distributed.

The large values of *LM** correspond to estimating non-stationary residuals and will result in rejection of null hypothesis of cointegration (equivalent to rejecting the stationarity of the errors). Rejection of *LM** concludes that the average of individual *LM*-statistics across the countries in the panel is far away from the mean μ_v, constructed under the null hypothesis.

4. EMPIRICAL RESULTS

The existence of long-run relationship is examined using two types of cointegration tests. The individual country cointegration analysis is conducted using the multivariate cointegration test developed by Johansen (1988). This technique is applied to countries whose exchange rates and interest rate differentials were established as being I(1) series. The null hypothesis of the Johansen test is that of

non-cointegration against the alternative of cointegration.   We estimate both Johansen Max and Trace Statistics for each model since these tests are now well known, we do not elaborate on them here.   For the panel cointegration test, we exploit the method of McCoskey and Kao (1998), who have derived a residual based test for heterogeneous panel setting.

4.1. Johansen Cointegration Results

The results from Johansen Cointegration analysis are summarised in Table 2, where both the Max and Trace statistics examine the null hypothesis of non-cointegration against the alternative of cointegration. In case of real exchange rate and real long-run interest rate differential, with a constant equilibrium exchange rate there is a strong long-run relationship between real exchange rate (REX) and real interest rate differential, in five out of ten Asian countries.

But in real short-run interest rate differential and real exchange rate, only Sri Lanka fail to rejected the null hypothesis of non-cointegration. Trace statistics gave a very strong evidence about the relationship between real exchange rate and real short-run interest rate differential. Because in case of nine Asian countries out of ten Asian countries have been rejected the null of non-cointegration.

Table 2

Single Country Johansen Tests

	Exchange Rates and Long-run Interest Rate Differential				Exchange Rates and Short-run Interest Rate Differential			
	Null (Max.Eg.Val.)		Null (Trace)		Null (Max.Eg-Val)		Null (Trace)	
Countries	R=0	R<=1	R=0	R<=1	R=0	R<=1	R=0	R<=1
Bangladesh	23.38**	5.99*	29.37**	5.99*	27.52**	5.23*	32.75**	5.23*
India	11.75	5.03*	16.78	5.03*	13.21	7.31**	20.52*	7.31**
Indonesia	11.35	6.79**	18.14	6.79**	13.98	10.81**	24.79**	10.81**
Korea	9.19	7.75**	16.94	7.75**	18.45**	8.26**	18.45*	8.26**
Malaysia	9.53	5.46*	14.99	5.46*	15.96*	8.88**	24.84**	8.88**
Pakistan	22.71**	9.32**	32.03**	9.32**	22.99**	10.73**	33.72**	10.78**
Philippine	17.52**	5.23*	22.75*	5.23*	13.80	6.71**	20.51*	6.71**
Singapore	25.70**	8.76**	34.46**	8.76**	27.66**	14.13**	41.79**	14.13**
Sri Lanka	10.08	4.42*	14.50	4.42*	8.27	3.99*	12.26	3.99*
Thailand	12.40	6.91**	19.31*	6.91**	11.05	7.45**	18.50**	7.45**

 * Denotes significance at the 5 percent level.
 ** Denotes significance at the 1 percent level.

4.2. Dynamic Panel Data Results

4.2.1. *The Panel Unit Root Test Results*

The panel unit root test results are presented in Table 3. In the first case we assume that none of the individual series in our model contains a trend. This, it is assumed for each series, $Y_{i,t}$ that $E(\Delta Y^*_{i,t}) = 0$. This means that each series could contain a non-zero intercept but not a time trend. To test three series of REX, RLID and RSID for stationarity in our panel of 10 countries. We can use the ADF test given in Equation (8) to constant the appropriate $\psi_{\bar{t}}$.

As it is a one sided test, a statistic less than –2.18 at 1 percent, –1.99 at 5 percent and –1.88 at 10 percent would cause rejection of null hypothesis of non-stationarity. At P=0 only SRID would reject the null hypothesis of non-stationary at 1 percent. At P=1, RLID and RSID reject the null at 1 percent. And at P=2 only RSID reject the null hypothesis of non-stationary at 5 percent. However, our assumption that without time trend may be over restrictive. Therefore we test stationarity again allowing for a time trend. In this case only RSID(P=1) reject the null hypothesis at 1 percent.

The results indicate that real exchange rate in both cases, without time trend and with time trend has a unit root (Non-stationary). The results with respect to real interest rates (RLID, RSID) are ambiguous, in some cases that real interest rates are stationary. So we can not use traditional method (OLS). In conducting the panel cointegration test, we therefore present panel estimates based on the panel of ten countries.

4.2.2. *Results for Panel Cointegration*

The existence of long-run relationships is examined using LM* test for the null hypothesis of cointegration. Our panel LM* test statistic, reported in Table 4, provide clear empirical evidence for the existence of a statistically significance, long-run RERI relationship in both long-term interest rate and short-term interest rate. For the panel of ten countries, the estimated value of the LM* provide a clear evidence of fail to reject the null hypothesis of cointegration, first we checked the long-run relationship between real exchange rate and long-term real interest rate differential with time trend and without time trend and found that the null hypothesis of cointegration can not be reject, with LM* = –4.9273 (without time trend) and LM*= –6.735826 (with time trend) as compare to critical value at 1 percent = 4.63, (5 percent = 4.04, 10 percent = 3.74) and 1 percent = 6.78 (5 percent = 6.13, 10 percent = 5.78) respectively. Same procedure applied for REX and RSID and again found fail to reject the null hypothesis of cointegration as shown in Table 4. As the LM* test statistic has fail to reject the null hypothesis of cointegration, so we can say that there is a very strong long-run relationship between real exchange rate and real interest rate differentials, on the basis of a panel of ten countries result.

Table 3

Panel Unit Root Test (IPS Test)

Series	IPS-Statistics	Inference
P=0 without Time Trend		
REX	0.5594416	Fail to reject Ho
RLID	–1.36981925	Fail to reject Ho
RSID	–3.49830594	Reject Ho at 1 percent
With Time Trend		
REX	–0.14917817	Fail to reject Ho
RLID	–1.00691754	Fail to reject Ho
RSID	–2.11506186	Fail to reject Ho
P=1 without Time Trend		
REX	–0.52691167	Fail to reject Ho
RLID	–2.36243116	Reject Ho at 1 percent
RSID	–3.68738803	Reject Ho at 1 percent
With Time Trend		
REX	–2.25284296	Fail to reject Ho
RLID	–2.42930851	Fail to reject Ho
RSID	–2.98828813	Reject Ho at 1 percent
P=2 without Time Trend		
REX	0.10136921	Fail to reject Ho
RLID	–0.63270872	Fail to reject Ho
RSID	–2.12716841	Reject Ho at 5 percent
With Time Trend		
REX	–2.196236	Fail to reject Ho
RLID	–0.79718032	Fail to reject Ho
RSID	–0.73819947	Fail to reject Ho

Without Time Trend:
Critical value at 1 percent = –2.18.
Critical value at 5 percent = –1.99.
Critical value at 10 percent = –1.88.

With Time Trend:
Critical value at 1 percent = –2.79.
Critical value at 5 percent = –2.6.
Critical value at 10 percent = –2.51.

Table 4

Panel LM-FM Test

Series	LM-FM Statistic	Inference
Without Time Trend		
REX, RLID	–4.9273	Fail to reject Ho
REX, RSID	–3.4567	Fail to reject Ho
With Time Trend		
REX, RLID	–6.735826	Fail to reject
REX, RSID	–5.7658	Fail to reject

Without Time Trend:
Critical value at 1 percent = 4.63.
Critical value at 5 percent = 4.04.
Critical value at 10 percent = 3.74.

With Time Trend:
Critical value at 1 percent = 6.78.
Critical value at 5 percent = 6.13.
Critical value at 10 percent = 5.78.

5. CONCLUSION

The present study have empirically analysed the long-run relationship between real exchange rates and real interest rate differentials, using a panel data set for 10 Asian countries during the period 1971–2000. The empirical results using Johansen's technique provide strong evidence to reject the null hypothesis of non-cointegration in most of the developing countries. The trace statistics of Johansen's cointegration method indicate evidence of cointegration between real exchange rate and real short run interest rate differential in the case of nine out of ten Asian countries. Whereas cointegration between real exchange rate and real long-run interest rate differential appears in five cases according to trace statistics of Johansen method. The empirical results using LM-Panel cointegration method provide evidence of statistically significant long-run relationship for one currency pairing. However, the use of a panel cointegration test produced a failure to reject the null-hypothesis of cointegration in both cases—real exchange rate—real short run interest rate differential and real exchange rate—real long-run interest rate differential. We conclude that the result of panel cointegration test supports the results for individual countries long-run relationship between real exchange rate and real interest rate differentials.

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Comments

This paper explores the long-run empirical relationship between real exchange rate and real interest differentials between 10 Asian countries *vis-à-vis* the United States. The paper employs Johansen's maximum likelihood technique of cointegration as well as McCoskey-Kao (1998) residual-based cointegration technique based on a modified Lagrange Multiplier statistic designed to deal with panel data. While the results produced by the former technique lend support to a long-run relationship between the underlying series only in four Asian countries, Bangladesh, Pakistan, Philippine and Singapore, those produced by the latter technique provide much stronger support as panel cointegration cannot be rejected for all the countries.

First of all I would like to acknowledge that the authors have undertaken a commendable task by contributing a paper on the most recent topic of research, the relationship between real exchange rate and real interest differential. However, I have some observations about theoretical underpinning and some reservations about empirical validity of the underlying relationship. But before I turn to these points, let me make the following general comments on the paper.

Overall, the paper is not well written, and has some redundant details. For example, Section 1 can be shortened without having any significant loss to the theme of the paper. Similarly, there is absolutely no need for Section 3. These discussions are redundant because they have little to do with cointegration analysis of the underlying relationship. As for Section 3.1, it needs to be restructured now as an independent Section 3, covering the data description and econometric methodology employed in the paper. In particular, the second paragraph and Section 4.2 have too much redundant material and discussions. As for the second paragraph, studies such as Frankel (1979), Hooper and Morton (1982) and the others focusing on the nominal versions of the monetary model of exchange rate may better be put in the footnote, while only the studies such as Mease and Rogoff (1988) and others dealing directly with the underlying versions of the monetary model be discussed in the text. As for Section 4.2, many things are repetitious, for example the authors should avoid reporting the numerical estimates in the text once they have already been mentioned in Tables and concentrate only on brief interpretation of the results.

The title of the paper does not fully correspond to the main text of the paper. For example, while the authors have employed the Johansen maximum likelihood technique to examine long run relationship between the underlying series for each of 10 Asian countries in question as well as McCoskey-Kao (1988) technique to explore the long-run relationship for a pooled or panel data set of all the countries,

the title focuses mainly on panel cointegration analysis. This also requires omission of the many figures and their redundant explanations from Section 3.

The paper is also weak theoretically as well as empirically. As for theoretical underpinning, the authors have not been able to properly rationalise the underlying relationship. In Sections 1, I wonder if "Popular theories of exchange rate determination also predict a link between real exchange rates and real interest differentials" what are then other theories, which were first to predict the underlying relationship. I also wonder what are popular theories of exchange rate determination.

As has been argued by Mease and Rogoff (1988), the underlying relationship is indeed a real versions of alternative rational expectations monetary models of exchange rate determination, which were developed by Dornbusch (1976); Frankel (1979) and Hooper and Morton (1982). In nominal versions of these models, the exchange rate is postulated to be determined by such fundamental as relative national money supplies, real incomes, short terms interest rates, expected inflation differentials and cumulated trade balances. In stochastic regression form, alternative nominal versions of the monetary model are given in the equation as follows:

$$S_t = \beta_0 + \beta_1 (m - m^*)_t - \beta_2 (y - y^*)_t + \beta_3 (r - r^*)_t + \beta_4 (\pi - \pi^*)_t + \beta_5 (TB - TB^*)_t + u_t$$

(1) Frenkel (1976) and Bilson (1978) flexible price monetary models of exchange rate determination postulate that PPP holds continuously such that $\beta_4 = \beta_5 = 0$.

(2) Dornbusch (1976) and Frankel (1979) sticky price and real interest differential monetary models of exchange rate determination postulate that PPP holds in the long run only such that $\beta_5 = 0$.

(3) Hooper and Morton (1982) equilibrium real exchange rate monetary model of exchange rates, which is implied by the above equation, assume unequal coefficients for the trade balance.

In fact, the authors have not been able to properly rationalise the derivation of the underlying relationship in Section 2. Moreover, they are mistaken about some relationships and the assumptions made in the derivation of the relationship. For example, as we have indicated above, almost all versions of the monetary model assume that PPP hold in the long run and therefore the real exchange rate is mean reverting in the long run but the authors do not start with the monetary model nor do they link the derivation of the relationship to the PPP concept. Conversely, it is surprising to note that the authors term Equation 2, which implies the so-called relative PPP, a real exchange rate identity. I do not think that real exchange rate is an identity because the real exchange of Pak rupee is probably not one and the same time series so long as it is measured in bilateral terms.

I wonder why the authors believe that there is no particular theory to predict the expected level of real exchange rate. The authors would not have passed such a

sweeping judgement that "there is no particular economic theory to predict the expected level of real exchange rate" if they had reviewed the literature on mean reversion in real exchange rate as well on *ex ante* purchasing power parity. Perhaps the authors wish to say that one cannot empirically estimate the expected real exchange rate. As for the empirics of the expected real exchange rates, one should not forget that there are several alternative expectations mechanisms, such as adaptive expectations and rational expectations mechanisms and the like, that may be employed to deal with the expected variable. At this, it would not be impertinent to mention that the authors should have used rational expectations mechanism, which is more appropriate than the one-sided moving average filter mechanism, to estimate the expected inflation rate.

Although the authors correctly take expectations and leads on both sides of Equation 2 and then substitute the resulting equation into Equations 1 and 3 to obtain Equation (4), but they are mistaken to believe that the expected real exchange rate is constant over time because it is unobservable. The real exchange rate expected to prevail to at time $t + 1$ may be assumed to be constant over time, but the question is what about the real exchange rate that is observable at time t. Are there any differences between the statistical properties of the two time series? My observation is that the statistical properties of the current real exchange rate and the future real exchange rate, that is extracted using rational expectations, are not significantly different.

It is also important to note that domestic and foreign real interest rates are not observable at time t; rather they are *ex ante* and are observable at time $t+1$. Therefore, Equation (1) as well as Equation (5) will change as follows:

$$REX_t = E_t REX_{t+1}^{e} - (r_{t+1}^{e} - r_{r+1}^{*e})$$

Moreover, it is also important to note that if we move the real exchange rate series to one side and the interest differential to the other and make the assumptions that the *ex ante* PPP holds, implying that expected changes in real exchange rates are mean zero serially uncorrelated, then real interest parity will hold precisely and the real exchange rate will tend to follow a random walk, and not a stationary process. As a consequence, the main assumption of all versions of the monetary model that the real exchange rate is mean reverting over time will no long hold now.

$$E_t REX_{t+1}^{e} - REX_t = (r_{t+1}^{e} - r_{r+1}^{*e}) = \upsilon_{t+1}$$

$$r_{t+1}^{e} = r_{r+1}^{*e} + \upsilon_{t+1}$$

The belief that the real exchange rate tends to be equal to the real interest differential across countries is not theoretically as well as empirically valid. However, it is true that expected depreciation of the home currency tends to be equal to the extent domestic real interest rate is higher than the foreign interest rate. This is consistent with *ex ante* PPP view implying that the real exchange rate follows a random walk.

I have also reservations about the author's empirical finding that there is unit in the real interest differential but have no problem with the evidence that the real exchange rate follows a random walk. However, if the random walk hypothesis is not rejected about the real exchange rate, then my reservation will be reinforced that the real exchange rate cannot be equal to the real interest differential; rather it is changes in expected real exchange rates that tend to be equal to the real interest differential. There is now overwhelming evidence to indicate that real interest differential is mean reverting over time. I wonder why the authors have not bothered to explore for the existing empirical evidence as to where do we stand today regarding the empirical behaviour of the real interest differentials around the world. For example, Moosa and Bhatti (1995); Moosa and Bhatti (1996,a,b) and Moosa and Bhatti (1997) were able to find overwhelming evidence that real interest differentials are stationary in most of industrial countries as well as in Asia. In their paper (1996b), Moosa and Bhatti also examined mean reversion in real interest rates in four Asian countries such as Korea, Malaysia, Philippine and Singapore that the authors have analysed. Real interest differentials of all these countries were stationary even when the Dickey-Fuller statistics was used. Therefore, I believe that if unit root tests were properly run the real interest differential would not turn out be nonstationary.

More precisely, I have reservations about the use of the Dickey-Fuller unit root test, which involves a problem of serial correlation. In particular, I have suspicions about the precision of the author's strategy of fixing the minimum lag in implementing the Dickey-Fuller test empirically. My conjecture is reinforced by the author's conclusion on page 13 that "the results with respect to real interest rate are ambiguous, in some cases that real interest rates are stationary".

I have also concern about the coefficients of real interest differentials. Perhaps the authors avoided reporting coefficients of real interest differentials because they knew that those were not statistically significant.

Razzaque H. Bhatti

International Islamic University,
Islamabad.

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