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SYMMETRIC AND ASYMMETRIC NONLINEAR DYNAMICS IN REAL INTEREST RATE PARITY

Abstract. *This study analyzes the validity of the real interest rate parity hypothesis for 16 emerging market countries using Japan and United States as base countries for the post-1990 period. We use a recently introduced nonlinear test which tests the null hypothesis of unit root against the alternative of symmetric/asymmetric exponential smooth transition autoregressive model. The results show evidence in support of the real interest rate parity hypothesis for the all countries in the sample.*
Keywords*: Non-linearities; Real interest rate differentials; Unit roots; Asymmetric adjustment; Emerging Markets.*

JEL Classification: C22, E31

1. Introduction

The Real Interest Rate Parity (RIRP) hypothesis is one of the fundamental research topics in international economics and finance. The RIRP requires the Uncovered Interest Parity (UIP) and the (relative) Purchasing Power Parity (PPP) hold simultaneously so that arbitrage in international financial and goods markets prevents domestic real rates of return from deviating from the world real interest rate. With substantially removal of regulations and closer integration of international markets, global movements of interest rates have become increasingly linked. Therefore, the analysis whether real interest rates are equalized across countries is a matter of important interest for policymakers, academicians and international investors for a number of reasons. First, in an open economy, real interest rates are an important channel for transmission of macroeconomic policies. The policymakers always seek a better understanding of the fundamentals of the real interest rate. This is due to its significance in influencing investment and output decisions. It also can markedly affect macroeconomic dynamics, such as exchange rate pass-through and capital flows, and also the valuations of financial assets. Rose (1988), for instance, has brought up the subject regarding the conceivable instability of the ex ante real interest rate and the implications toward the standard intertemporal asset pricing models. Furthermore, the capabilities of domestic monetary and fiscal authorities will be limited in effectively stabilizing the domestic real rate relative to the world rates once the linkages exist (Pill and Pradhan, 1997). If the RIRP holds then, the effectiveness of national monetary policy as stabilization tool would be restricted to the extent that it can influence the world real interest rate (Mark, 1985). Furthermore, if real interest rates do not differ across countries then policies aimed at increasing domestic savings will not increase the rate of capital formation (Feldstein, 1983). In this respect, real interest rates play a key role in influencing economic activity through saving and investment behavior. Second, the validity of the RIRP provides an indication if countries are integrated or autonomous because the RIRP requires efficiency both in the goods markets (via PPP) and in the assets markets (via UIP). If the economies constitute strong economic relationships, then it is likely that unfavorable economic situations from one economy will be transferred to the others. In other words, a contagion effect will have taken place. These side-effects will scare away the confidence of borrowers to make investment in these regions. As a result, modeling the dynamics of the RIRP can thus be useful for policymaking purposes in recovering information on monetary and financial crises that countries may face. Third, the RIRP is a key assumption in the early models of exchange rate determination (*i.e.* Frankel (1976) and Frankel (1979)). Moreover, in sticky-price models, it is emphasized that in the short-run, non-zero real interest rate differentials are due to the rigidities (Mussa, 1976). In some portfolio balance models, it is argued that non-equality of real interest rates is the result of deviations from the UIP (*e.g.* Branson (1979)). Finally, the greater the degree of co-movement in international real returns, the smaller the potential benefits from international portfolio diversification.

The purpose of this study is to investigate the validity of long-run RIRP among the major emerging market countries using a new test introduced by Sollis (2009) which allows us to distinguish between the null of unit root and the alternative of symmetric/asymmetric Exponential Smooth Transition Autoregressive (ESTAR) model. The remainder of this paper is organized as follows: Section II explains the methodological issue and summarizes relevant empirical literature on the RIRP. The econometric methodology is explained in section III and in Section IV, we present the empirical findings. Section V concludes the paper.

2. Theoretical Background and Literature Review

The RIRP states that real returns on identical assets are equalized across countries. For domestic and foreign interest rates on appropriate assets with the same maturities, we may write:

$$s_{t+1}^{e} - s_t = i_t - i_t^{*} \qquad (1)$$

where s is the natural logarithm of the exchange rate, i is the nominal interest rate, e and * stand for expected and foreign value respectively. The (relative) PPP requires that the expected change in exchange rate responds to offset spreads in expected inflation across countries

$$\Delta s_{t+1}^{e} = \Delta p_{t+1}^{e} - \Delta p_{t+1}^{*e} \tag{2}$$

p shows the natural logarithm of the general price level and Δp^{e} refers to the expected rate of inflation. Combining (1) and (2) gives:

$$i_t - i_t^{*} = \Delta p_{t+1}^{e} - \Delta p_{t+1}^{*e} \tag{3}$$
$$i_t - \Delta p_{t+1}^{e} = i_t^{*} - \Delta p_{t+1}^{*e}. \tag{4}$$

Under the assumption that nominal interest rates satisfy Fisher relation, $r_t = i_t - \Delta p_{t+1}^{e}$ and $r_t^{*} = i_t^{*} - \Delta p_{t+1}^{*e}$ leads to the RIRP:

$$r_t = r_t^{*} \tag{5}$$

From the formula above, the RIRP links *ex ante* real interest rates to the UIP and the PPP conditions under Fisher parity relationship. The equalization of real interest rates in equation (5) requires that exchange rates and nominal interest rates are responsive to changes in expected inflation. Thus, *ex ante* real interest deviation can be written as

$$y_t = r_t - r_t^{*} \tag{6}$$

where y_t reflects the real interest rate differential (RID).

The RIRP above defined implies that the RID ($r_t - r_t^{*}$) is constant. According to Ferreira and Leon-Ledesma (2007), the RIRP implies that the RID is not constant but a stationary process, since the existence of adjustment costs and imperfect information prevents the RID from being constant at every point. If the RIDs are mean-reverting, the RIRP holds as a long-term equilibrium condition. The deviations from the RIRP arises due to the departures from UIP expressed in equation (1) and the extent of relative forecasting errors, which cause deviations from the PPP as expressed in equation (2).

There are some other factors render the RIRP to long run equilibrium. Balassa (1964) and Samuelson (1964) suggest that an increase in the relative productivity in the tradable-goods sector will increase wages not only in this sector but also in the non-tradables sector by raising the relative price of non-tradables. This suggestion, in turn, involves real appreciation, driving r_t below r_t^{*}. On the other hand, the positive RIDs may indicate premia due to currency-depreciation risk or country specific premia due to *e.g.* default risk, political risk, and discrepancies in tax rates. Transaction costs reflecting factors such as shipping costs and trade barriers limit the scope of arbitrage across international goods markets upon which PPP is based, leading to deviations of r_t from r_t^* (Sarno, 2005).

The validity of the RIRP has been investigated using various econometric methods and provides conflicting empirical evidence[1]. Early studies of testing the RIRP condition include Mishkin (1984) and Cumby and Mishkin (1986) who employ classical regression analysis and find against the RIRP. More recent studies that utilize the cointegration methodology include Goodwin and Grennes (1994) and Moosa and Bhatti (1996) who find support for the RIRP for various OECD countries. Arghyrou et al. (2009) provides greater support for the RIRP using unit root test that allow structural breaks. Recently, an interesting line of research that addresses the possibility of asymmetric or nonlinear dynamics of realignments towards the RIRP has been recently developed. For example, early work by Cavaglia (1992) notes the changing patterns in the behavior of real interest differentials over time by utilizing Kalman filtering techniques, while Fountas and Wu (1999) work within a cointegration approach that allows for structural breaks in the series and find evidence in favor of the RIRP in EU member countries. Pippenger and Goering (1993) and others argue that the presence of threshold nonlinearities reduces the power of standard unit root and cointegration tests. Indeed, Michael *et al.* (1997) show that cointegration or unit root tests may be biased when the linear alternative neglects nonlinearity of smooth transition autoregressive (STAR) type models. There is evidence from studies based on threshold autoregressive models that within some neutral bands of transaction costs, the likelihood of adjustment towards equilibrium is rather low. The evidence from the STAR models is also suggestive of a series of thresholds straddling the equilibrium conditions so that arbitrage opportunities increase with larger deviations from parity against a background of transaction costs. There is also a growing literature based on Markov-regime switching models. For instance, there is evidence from Dahlquist and Gray (2000) that the speed of adjustment of nominal interest rates in the European monetary system is stronger during periods of high interest rates and high volatility. Papers by Holmes and Maghrebi (2004 and 2006) and McMillan (2004) have found that the adjustment process towards equilibrium follows a non-linear process (*e.g.,* the STAR process). Similarly, Enders and Siklos (2001) have found evidence of asymmetries in nominal interest rates. Meanwhile, McMillan (2004) in his assessment of the long-run relationship between long- and short-term interest rates, has argued for a quicker reversion to the equilibrium when the long-term rate exceeds the short-term UK interest rates. Findings from these papers imply that the speed of the adjustment process is no longer constant. Thus, while the testing procedure of the standard unit root tests assumes a linear adjustment process to the equilibrium, *i.e.,* the speed of return from a position of disequilibrium is the same regardless of the magnitude of the deviation from the equilibrium, the non-linear models allow for differing speeds of adjustment back to the equilibrium value. As such, we can expect to find less favorable results on the international parity condition if non-linearity in the data generating process is neglected. An implication of nonlinear modeling of the RIRP is that the speed of adjustment towards the RIRP following a shock is likely to be positively related to the size of the shock. Such an insight is not available in the linear tests for mean reversion in real interest differentials or standard cointegration tests between domestic and foreign real interest rates. Furthermore, if real interest differentials can be characterized by nonlinearities, then linear approaches to nonlinear problems of monetary policy and integration would be inappropriate.

3. Econometric Methodology

In this study, we use the concept of mean stationarity to evaluate the RIRP hypothesis. If the deviations from the RIRP are stationary, then even if the condition does not hold in the short run, it holds in the long-run since deviations from parity are transitory. A stationary time series will revert back to its equilibrium value after being disturbed by shocks. On the other hand, if the deviations from parity are not stationary, shocks can lead to permanent deviations from equilibrium so that the RIRP does not hold in the long-run.

Kapetanious et al. (2003) proposed a nonlinear test to test for the null hypothesis of unit root against the alternative of nonlinear ESTAR model. But since this test assumes symmetry under the alternative, Sollis (2009) introduced a new test which allows choosing between symmetric and asymmetric ESTAR model by using a standard *F* test.

In his paper, Sollis develops the following asymmetric ESTAR (AESTAR) model:

$$\Delta y_t = G_t\left(\gamma_1, y_{t-1}\right) \times \left\{S_t\left(\gamma_2, y_{t-1}\right)\rho_1 + \left(1 - S_t\left(\gamma_2, y_{t-1}\right)\right)\rho_2\right\} y_{t-1} + e_t \tag{7}$$

where $G_t\left(\gamma_1, y_{t-1}\right) = 1 - \exp\left(-\gamma_1\left(y_{t-1}^2\right)\right)$, ($\gamma_1 \geq 0$) shows an exponential function while $S_t\left(\gamma_2, y_{t-1}\right) = 1 \Big/ \left[1 - \exp\left(-\gamma_2\left(y_{t-1}\right)\right)\right]$, ($\gamma_2 \geq 0$) shows a logistic function. This model can be augmented to allow for higher order dynamics:

$$\Delta y_t = G_t\left(\gamma_1, y_{t-1}\right)\{S_t\left(\gamma_2, y_{t-1}\right)\rho_1 + \left(1 - S_t\left(\gamma_2, y_{t-1}\right)\right)\rho_2\} \times y_{t-1} + \sum_{i-1}^{k} \beta_i \Delta y_{t-i} + e_t \tag{8}$$

In Sollis' test, at first stage we test the null of unit root against the alternative of symmetric/ asymmetric ESTAR model. But the null of unit root ($H_0 : \gamma_1 = 0$) cannot be directly tested, since there are unidentified parameters under the null. To circumvent this problem, assuming *k=0*, Sollis suggests to take a first-order Taylor expansion of $G_t\left(\gamma_1, y_{t-1}\right)$, but since there are still unidentified parameters under the null, Sollis simplifies the model by taking a Taylor expansion of the logistic function and obtains following model by making some replacements[2]:

$$\Delta y_t = \theta_1 y_{t-1}^3 + \theta_2 y_{t-1}^4 + \eta_t \tag{9}$$

This model can be augmented as follows;

$$\Delta y_t = \theta_1 y_{t-1}^3 + \theta_2 y_{t-1}^4 + \sum_{i=1}^{k} \kappa_i \Delta y_{t-1}^3 + \eta_t \tag{10}$$

We can test the null of unit root which becomes ($H_0 : \theta_1 = \theta_2 = 0$) by using an F test (F_n) but since standard critical values cannot be used, Sollis (2009) tabulated relevant critical values in his paper. For the non-zero mean or deterministic trend cases, we use demeaned or detrended series of interest instead of y_t in equation (10). On the condition that we reject the null hypothesis, we can pass to the second stage where we test the null hypothesis of symmetric ESTAR ($H_0 : \theta_2 = 0$) model against of the asymmetric ESTAR ($H_0 : \theta_2 \neq 0$) nonlinearity by employing a standard F-test (F_{std}). But using the critical values only asymptotically valid if the consistent least squares (LS) estimate of θ_1 is negative.

4. Data and Empirical Results

The data for empirical research consists of RIDs for a pool of emerging market countries (Argentina, Brazil, Chile, China, Hong Kong, Indonesia, India, Korea, Malaysia, Mexico, Philippines, Singapore, South Africa, Sri Lanka, Thailand and Turkey). Japan and USA was used as the reference countries for the calculation of RIDs. The end of the sample is 2009 M12 for all countries except for Chile, India, Sri Lanka, and Malaysia for which we have RIDs until 2009M10, 2009M1, 2008M12 and 2009M1 respectively. The start of the sample is generally 1990M1. Exceptions for this start date of the sample are Argentina, Brazil, China, Hong Kong and Mexico. As it is well known, Argentina, Brazil and Mexico experienced financial crises and several episodes of hyperinflation during the 1990s. Therefore and also since the intractability of the data, we have chosen to leave the high inflation and crises years out of the sample. For Argentina we start from 1992M1 as this is the date for which stable and low inflation is reflected in the data as a response to the 1991M4 convertibility plan. The monetary change of the Brazilian Real Plan started in 1994M7 and hence we decided to use the sample from 1996M1. For Mexico, we start from 1997M1. Because of the lack of the data, we start in 1994M1 for China and Hong Kong.

We obtained the data from IMF's International Financial Statistics (IFS). Due to data accessibility, we used deposit rate for Argentina, Chile, China and Turkey, money market rate for Brazil, Hong Kong, Korea, Philippines, South Africa, Thailand, Indonesia, Japan, Singapore and Sri Lanka, 3 months treasury bill rate for Malaysia and Mexico, federal funds rate for USA, and commercial lending rate for India. Following Ferreira and Leon-Ledesma (2007); in order to calculate RIDs, we transformed the annualized monthly interest rate into a compounded quarterly rate; the real interest rate at time *t* was then calculated by subtracting the quarterly average of the 12-month inflation ahead of period *t*. Our analysis, therefore, is based on real rates of return on investments lasting for 3 months and these are used to obtain RIDs. The inflation rate is the rate of growth of the Consumer Price Index.

We test the RIRP hypothesis for the 16 emerging markets. To make a comparison for Sollis' test, we employ the ADF unit root test first. Table 1 presents the results. We couldn't reject the null of unit root for 4 of 16 countries, with Japan based series by employing the ADF unit root test. The results show that Argentina-Japan, Chile-Japan, China-Japan, Indonesia-Japan, India-Japan, Korea-Japan, Malaysia-Japan, Mexico-Japan, Philippines-Japan, Sri Lanka-Japan, Thailand-Japan and Turkey-Japan pairs are stationary, so the RIRP hypothesis is valid for these countries when we use Japan as the base country. On the other hand, we found Argentina-USA, Chile-USA, Indonesia-USA, India-USA, Korea-USA, Mexico-USA, Philippines-USA, Singapore- USA, South Africa-USA, Sri Lanka-USA, Thailand-USA and Turkey-USA pairs as stationary which show evidence that RIRP holds for these countries when USA used as the reference country.

Table 1. Results of the ADF test

	Japan Based	
Countries	*Test Statistic*	*Lag*
Argentina	-3.6498*	4
Brazil	-2.576	2
Chili	-2.7455***	11
China	-2.7346***	1
Hong Kong	-1.9285	1
Indonesia	-2.9588**	2
India	-3.8452*	1
Korea	-2.7147***	1
Malaysia	-3.2822**	5
Mexico	-3.3560**	0
Philippines	-5.0616*	1
Singapore	-2.1829	2
South Africa	-2.036	1
Sri Lanka	-7.2136*	0
Thailand	-3.5650*	0
Turkey	-5.3671*	0
	USA Based	
Countries	*Test Statistic*	*Lag*
Argentina	-3.6543*	4
Brazil	-2.1418	2
Chili	-4.1035*	11
China	-2.4746	1
Hong Kong	-2.203	1

Indonesia	-3.3161**	2
India	-4.0002*	1
Korea	-2.9830**	1
Malaysia	-2.3498	3
Mexico	-3.8241*	0
Philippines	-4.3774*	2
Singapore	-2.7236***	2
South Africa	-2.9176**	1
Sri Lanka	-7.4600*	0
Thailand	-3.5572*	1
Turkey	-5.4968*	0

Note: Optimal lag length chosen using by Schwarz Information Criteria.
, ** and * show the rejection of the null of unit root at 1%, 5% and %10 levels respectively.*

Despite the ADF unit root test provide evidence for the RIRP hypothesis for most of the country pairs, this test loses power when the series under investigate are nonlinear. So we follow Baharumshah et al. (2009) and take into account the possibility of nonlinearity in the pairs by applying Sollis' nonlinear test to discriminate between unit root process and nonlinearity. Table 2 presents the results of the Sollis' test. We reject the null of unit root for all the pairs by using both Japan and USA as the base country that shows the RIRP hypothesis is valid for all the countries in the analysis. We find asymmetry in 9 of 16 countries using USA as base country and 6 of 16 pairs using Japan as referenced country. As pointed out by Ferreira and Ledesma (2007) the asymmetry is an important characteristic for explaining RIDs, suggesting that increases in interest rates can be perceived as a signal by lenders that determines their probability of bankruptcy, on the other hand in the cases when decreases experienced in real rates of interest, investors can under price risk which can cause them to undertake increased speculative investment as emphasized by Cooray (2009).

Table 2. Results of the Nonlinear Test

Japan Based

Countries	F_s	F_{std}	*Result*
Argentina	9.9568 (4)	8.5119	AESTAR
Brazil	24.8973 (1)	9.0574	Nonlinear*
Chile	22.5139 (11)	43.9509	AESTAR
China	8.9453 (7)	3.7926	SESTAR
Hong Kong	16.6965 (1)	10.017	AESTAR

Indonesia	8.0861 (2)	11.9916	AESTAR
India	9.1256 (1)	2.7133	SESTAR
Korea	6.7860 (1)	0.2734	SESTAR
Malaysia	5.6009 (5)	4.3504	AESTAR
Mexico	11.2819 (1)	0.7539	Nonlinear*
Philippines	13.8865 (12)	1.5172	SESTAR
Singapore	15.7786 (1)	1.062	SESTAR
South Africa	5.2736 (6)	2.3379	SESTAR
Sri Lanka	117.7069 (3)	109.4429	Nonlinear*
Thailand	4.8759 (2)	0.1737	SESTAR
Turkey	41.1139 (3)	25.5768	AESTAR

USA Based

Countries	F_s	F_{std}	*Result*
Argentina	10.6584 (4)	9.6123	AESTAR
Brazil	8.3325 (1)	0.367	SESTAR
Chile	26.3843 (11)	23.2488	AESTAR
China	10.5046 (8)	5.9439	AESTAR
Hong Kong	20.54910(1)	9.958978	AESTAR
Indonesia	8.5953 (2)	13.2059	AESTAR
India	7.0067 (1)	1.1779	SESTAR
Korea	11.7664 (1)	0.4148	SESTAR
Malaysia	9.3745 (1)	6.9231	AESTAR
Mexico	12.6375 (1)	0.2502	SESTAR
Philippines	28.0895 (12)	13.0178	AESTAR
Singapore	15.9837 (1)	9.3053	AESTAR
South Africa	6.6619 (1)	1.6656	SESTAR
Sri Lanka	116.7271 (3)	106.6392	Nonlinear*
Thailand	9.9110 (2)	0.6833	SESTAR
Turkey	40.8599 (3)	26.1949	AESTAR

Note: Numbers in brackets show the optimal lag length chosen by using Schwarz Information Criteria

** shows the LS estimate of θ_1 is not negative so we cannot choose between AESTAR and SESTAR.*

5. Conclusions

This study explores whether the Real Interest Rate Parity is valid for 16 emerging markets. The main contribution made by this article to the literature on RIRP is in terms of the econometric methodology. Rather than relying upon conventional linear unit root tests which suffer from power deficiency, we analyzed the RIRP hypothesis by using a nonlinear test which enables us to choose between asymmetric and symmetric nonlinearity. The results indicate the existence of long-run equilibrium of the RIRP and adjustment of the deviations of the long-run equilibrium is asymmetric for some countries. These empirical findings suggest that emerging market economies analyzed in this study are integrated and monetary and fiscal policies should regard the foreign market interest rates to affect savings and investment decisions and also to stabilize the national economy.

Notes:

1) For a survey for the RIRP, please refer to Alper et. al. (2009).
2) For the sake of brevity, we do not give the details of the modifications, please refer to Sollis (2009) for the details to obtain the Model 3.

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