International Review of Accounting, Banking and Finance
Vol 4, No.3/4, Fall/Winter 2012 Pages 1~15

IRABF

Real Interest Rate Parity for East Asian Countries Based on China with Two Structural Breaks

Hsu-Ling Chang,[a] Yan Liu[b], Chi-Wei Su[c]

a. Department of Accounting and Information, Ling Tung University

b. Department of Finance, Ocean University of China

c. Department of Finance, Ocean University of China

ABSTRACT

This study applies Narayan and Popp's (2010) unit-root test with two endogenous breaks, which has been proven to be more powerful than the other unit root tests with two breaks (Narayan and Popp, 2013) to test the validity of long-run real interest rate parity (RIRP) to assess the non-stationary properties of the real interest rate convergence relative to China for ten East Asian countries. We examine the validity of RIRP from the perspective of the unit root with two breaks and provide robust evidence, which clearly indicate that RIRP holds true for six countries. Our findings point out their real interest rate convergence is mean reversion towards RIRP equilibrium values with two structural breaks. It implies that the choices and effectiveness of the monetary and fiscal policies in the East Asian economies will be highly influenced by external factors originating from China. Our results have important policy implications for these East Asian countries under study.

Keywords: Unit Root Test with Two Endogenous Breaks, Real Interest Rate Parity

JEL: C22, F36

1. Introduction

The extent to which rates of real interest are connected across countries, and how these linkages have progressed over time, have gained considerable attention in previous studies (Fraser and Taylor, 1990; Anoruo *et al.*, 2002; Holmes, 2002; Pipatchaipoom and Norrbin, 2008). In an open economy, real interest rate parity (RIRP) provides an indication of whether countries are economically and financially integrated or autonomous. When RIRP holds, it implies that assets with identical risk, liquidity and maturity have the same expected return across different countries. The RIRP states that, if agents make their forecasts using rational expectations and arbitrage forces are free to act in the goods and assets markets, then real interest rates between countries will equalize (Peel and Venetis, 2005). RIRP requires good and financial market arbitrage, and its confirmation is viewed as an indication of macroeconomic convergence (Frankel, 1991). In theory, in a one-world market, investors should be able to allocate their capital freely, thereby reducing arbitrage opportunities across countries. In such an environment of growing interdependence among markets, country-specific interest rates should exhibit a long-run convergence. Importantly, verification of real interest rate equalization across countries implies evidence of capital mobility and financial integration. As globalization and integration of international goods markets advance with lessening of tariffs and other constraints, there will be further impetus to the changes in the financial market. Market integration has far reaching implications for cross-border capita; flows, arbitrage, financial management, and monetary policy autonomy. Another important implication is the loss of independence in the individual monetary authorities in controlling the internal real interest rates. If RIRP holds, that means one individual country could not pursue an independent monetary policy; thus, the country may lose the power to influence the real economy. In an open and effective financial market, the interest rate differentials between two countries may cause international capital flows, and then may induce the change of exchange rate. The arbitrage space will decrease due to the change of the exchange rate, until the financial market returns to the equilibrium status (Obstfeld and Rogoff, 1995; Merlevede *et al.*, 2003).

Increasing financial liberalization in East Asian countries since the mid-1980s has fuelled a lively debate regarding the optimum exchange rate regime for the region. Massive inflows of capital into these countries following their economic liberalization and financial deregulation in the early 1990s and following played a key role in this respect, and these inflows are not likely to diminish as these countries continue to deregulate and liberalize their financial markets. East Asian countries, which possess similar characteristics after undergoing various stages of financial liberalization provide a good platform for the study of financial integration (Baharumshah *et al.*, 2005). With the liberalization of interest rates due to the open market policy and deregulation of financial markets, interest rates in the East Asian countries are expected to rise in the long term and are expected to be closely connected with the global markets. Therefore, the features of East Asian countries provide an interesting study of RIRP hypothesis test. First, East Asia is of growing importance in the global economy especially China,[1] but the financial linkages among its numbers have yet to be systematically investigated. The rise of the China economy in recent decades and the rigorous liberalization of the China financial system following the entrance of China into the World Trade Organization (WTO) in 2001 have attracted researchers to examine the regional financial integration with respect to China. Furthermore, China has yet to further liberalize its financial system and it will overtake Japan as a leading financial centre or anchor country for common currency area in this region. Second, the emerging market economies of East Asian countries have removed their regulatory measures at different stages of their economic development. Despite these developments and the increasing importance of China in the world economy, very few studies have looked at China's connection with other countries. Third, and most of all, the initial conditions for East Asian countries transition varied extensively, and they may be an important indicator in explaining the magnitude of deviations from RIRP.

As for methodology, most studies of RIRP use conventional unit root tests such as the Augmented Dicky Fuller (1981, ADF) and Phillips and Perron (1988, PP) – but fail to reject the unit root hypothesis. The linear unit root test methodology assumes that in spite of the

---

[1] China is now the second largest economy in the world, only behind the U.S. It is also the third largest in terms of trade and Foreign Direct Investment (FDI) inflows.

deviation, the process of the real interest rate moving to the equilibrium is linear, and the velocity of adjustment is a constant. However, in the data generating process (DGP), if the nonlinear factors were neglected, we cannot receive the expected results via RIRP. The linear model critically underestimates the velocity of adjustment of long-term equilibrium, and usually we accept the null hypothesis because of the low power of the traditional unit root test. The omission of some structural breaks is a possible cause of the traditional unit root tests failing to reject the null hypothesis for stationarity. Perron (1989) argues that if there is a structural break, the power to reject a unit root decreases when the stationary alternative is true and the structural break is ignored. Meanwhile, structural changes presented in the DGP, but neglected, sway the analysis toward acceptance of the null hypothesis of a unit root. As we know, interest rates might be affected by internal and external shocks generated by structural changes, which may be subject to considerable short-run variation. It is important to know whether or not the real interest rate has any tendency toward a long-run equilibrium level, because the RIRP hypothesis requires that real interest rate revolves around a constant or a time trend. If the real interest rate is found stationary by using the unit root test with structural break(s), as a result the effects of shocks such as real and monetary shocks that cause deviations around a mean value or deterministic trend to be only temporary. Cuestas and Harrison (2010) provide evidence showing that the existence of structure changes in the RIRP might imply broken deterministic time trends and the result supports the RIRP.

As discussed, traditional unit root tests lose power if structural breaks are ignored. The general method to account for breaks is to approximate them with dummy variables. Accordingly, Zivot and Andrews (1992, hereafter, ZA), Perron (1997) and Lumsdaine and Papell (1997, hereafter, LP) account for endogenous structural breaks. However, Lee and Strazicich (2001, 2003, hereafter, LS) argues that ZA and LP models do not allow for a break under the null, and Perron (1997) does not model the break as an innovational outlier (IO), which may result in an over rejection of the unit root null. To handle this problem, Lee and Strazicich (2001, 2003) use a minimum Lagrange multiplier (LM) unit root test. Popp (2008) points out that the root of over rejection is that the parameters associated with structural breaks have different interpretations under the null and alternative hypotheses of testing models. Following Schmidt and Phillips (1992), Narayan and Popp (2010) consider two innovational outlier (IO) types specifications, that is, two breaks in the level and two breaks in the level and slope of a trending data series with unknown break times. Narayan and Popp (2010) test allows the generation of a new ADF-type unit root test and generates critical values by assuming unknown break dates with correct size, stable power and identifying the structural breaks accurately.

The central aim of this study contributes significantly to this field of research, because, first of all, we examine evidence for RIRP for 10 East Asian countries, using the unit root process with two structure breaks of real interest rate differentials against China and the test statistics suggested by Narayan and Popp (2010). Secondly, to the best of our knowledge, this study is the first of its kind to utilize the unit root test with two structure breaks in evidence for RIRP at China's connection with the East Asian countries. The empirical results have important policy implications for these transition countries under study.

The remainder of this study is organized as follows. Section 2 describes the methodology of the unit root test with two endogenous breaks proposed by Narayan and Popp (2010). Section 3 presents the data used in our study and discusses the empirical findings. Finally, Section 4 reviews the conclusions we draw.

2. The Theory of Real Interest Rate Parity & Narayan and Popp (2010)'s Unit-root Test with Two Structural Breaks

The RIRP theory contends that the real interest rate between two countries should be equal (Taylor and Sarno, 2004; Mark and Moh, 2005). According to Ferreria and L´eon-Ledesma (2007), RIRP defines that real interest rate differential is constant. Real interest rate differentials can be calculated using either en-ante or ex-post real returns, as well as alternative definitions for nominal interest and inflation rates. Following the majority of existing studies we use ex-post real returns so as to bypass the empirically tricky subject of approximating empirically inflation expectations. In this section, we test the threshold effect on the unit root process of the real interest rate differential series r_t using the unit-root with two structural breaks model developed by Narayan and Popp (2010, hereafter NP).

Following Narayan and Popp (2010), The DGP of a time series r_t is described as:

$$r_t = d_t + \mu_t \quad (1)$$

$$u_t = ru_{t-1} + e_t \quad (2)$$

$$e_t = A(L)^{-1} B(L)e_t \quad (3)$$

with d_t being the deterministic component, u_t being the stochastic component and $e_t \sim i.i.d.(0, \sigma_e^2)$. It is assumed that the roots of the lag polynomials *A*(*L*) and *B*(*L*), which are of order *p* and *q*, respectively, lie outside the unit circle. The NP unit root test considers two specifications both for trending data, one allows for two breaks in level (denoted M1 hereafter) and the other allows for two breaks in level as well as slope (denoted M2 hereafter). The IO-type models for M1 and M2 are given as follows, respectively:

$$d_t^{M1} = a + btA(L)^{-1} B(L)e_t (L)(q_1 DU_{1,t} + q_2 DU_{2,t}) \quad (4)$$

and

$$d_t^{M2} = a + btA(L)^{-1} B(L)e_t (L)(q_1 DU_{1,t} + q_2 DU_{2,t} + g_1 DT_{1,t} + g_2 DT_{2,t}) \quad (5)$$

with $DU'_{i,t} = I(t > T'_{B,i})$ and $DT'_{i,t} = I(t > T'_{B,i})(t - T'_{B,i})$, i = 1,2. Here, $T'_{B,i}$, i = 1,2, denotes the structural break dates. The parameters, q_i and g_i, indicate the magnitude of the level and slope breaks, respectively. The inclusion of $A(L)^{-1} B(L) e_t$ in Equations (4) and (5) enables the breaks to occur slowly over time. The unit root test models for M1 and M2 are presented respectively as follows.

$$r_t = \rho r_{t-1} + \alpha_1^* + \beta_1^* t + \delta_1 DU'_{1,t-1} + \delta_2 DU'_{2,t-1} + \theta_1 D(T'_B)_{1,t} + \theta_2 D(T'_B)_{2,t} + \sum_{j=1}^{k} \beta_j \Delta r_{t-j} + e_t \quad (6)$$

and

$$r_t = \rho r_{t-1} + \alpha_1^* + \beta_1^* t + \delta_1 DU'_{1,t-1} + \delta_2 DU'_{2,t-1} + \theta_1 D(T'_B)_{1,t} + \theta_2 D(T'_B)_{2,t} + \gamma_1 DT'_{2,t-1} + \gamma_2 DT'_{2.t-1} + \sum_{j=1}^{k} \beta_j \Delta r_{t-j} + e_t \quad (7)$$

NP tests the unit root null hypothesis of $\rho = 1$ against the alternative hypothesis of $\rho < 1$. Specially, NP makes use of a sequential grid search procedure comparable to Kapetanios (2005) according to the maximum absolute *t*-value of the break dummy coefficient θ_1 under the restrictions $\theta_2 = \delta_2 = 0$ for M1 and $\theta_2 = \delta_2 = \gamma_2 = 0$ for M2. That is,

$$\hat{T}_{B,1} = \arg\max_{T_{B,1}} \left| t_{\hat{\theta}_1}\left(T_{B,1}\right) \right| \quad (8)$$

Under the restriction of the first break, $\hat{T}_{B,1}$, NP estimates the second $\hat{T}_{B,2}$ analogously to the first break by:

$$\hat{T}_{B,2} = \arg\max_{T_{B,1}} \left| t_{\hat{\theta}_1}\left(\hat{T}_{B,1}, T_{B,2}\right) \right| \quad (9)$$

The new ADF-type test is invariant approximately to level and slope breaks in finite samples by means of Monte Carlo simulations.

3. Data and Empirical Results

We use monthly data from 1994:01 to 2011:06 to apply the unit root test with two structural breaks proposed by Narayan and Popp (2010) to test the validity of RIRP. During this time span, because of the increasing financial liberation and financial deepening, the East Asian countries accelerate the space of connecting the world economy. Including China, the emerging market economies of ASEAN have removed their regulatory measures at different stages of their economic development. Additionally, the deregulation process in these countries are varied in terms of timing and intensity (Phylaktis, 1999), with China being the last to enter the race following the country’s accession to the WTO. The data of our empirical study consist of 10 countries and regions: Hong Kong, Indonesia, Japan, Korea, Malaysia, Mongolia, Philippine, Singapore, Taiwan and Thailand. In order to compute real interest rates, the actual rates of inflation are derived from the annual increase in the Consumer Price Index (CPI). For Nominal interest rate we use money market rate or discount rate, specifically, Hong Kong, Indonesia, Japan, Korea, Malaysia, Mongolia, Philippine, Singapore, and Thailand (Money Market Rate), and China and Taiwan (Discount Rate). All data are taken from the CEIC DATA. We have then computed the interest rate differentials for 10 East Asian countries and regions against the China as a foreign counterpart.

For comparison, several univariate unit root tests, ADF, PP and the Kwiatkowski *et al.* (1992, KPSS), are first employed to examine the null of a unit root in RIRP for these 10 East Asian countries that we study. The result in Table 1 clearly shows the ADF and PP tests fail to reject the null of non-stationary for East Asian countries except for Philippine and Taiwan. KPSS test also show the same results. There is no question that three univariate unit root tests— ADF, PP and KPSS all fail to reject the null of non-stationary RIRP for these countries. The result implies that RIRP not hold East Asian countries relative to China during the sample period. However, the low power of ADF, PP and KPSS tests come from the convergence of real interest rates and the ignorance of structural changes. Therefore, these tests tend to accept the hypothesis of a unit root when the stationary alternative is true.

< Table 1 is inserted about here>

As stated earlier, there is a growing consensus that conventional unit root tests such as the ADF and PP tests - fail to incorporate the structural breaks in the model have low power in detecting the mean reversion of real interest rate. Perron (1989) argued that if there is a structural break, the power to reject a unit root decreases when the stationary alternative is true and the structural break is ignored. Meanwhile, structural changes present in the DGP, which have been neglected, sway the analysis toward accepting the null hypothesis of a unit root. Therefore, we proceed to test the real interest rate convergence by using the NP's (2010) unit root test with two endogenous breaks.[2] Table 2 reports the results of unit root test with two endogenous breaks on the real interest rate differential. As we can see from Table 2, the null hypothesis of the unit root in real interest rate differential reject for six of the countries studied here, and they are Hong Kong, Indonesia, Korea, Philippine, Taiwan and Thailand. One notable characteristic is that most of the individual time series were affected the

[2] We only consider a specification with a constant but without a time trend because time trend in real interest rate differential is not consistent with the long-run RIRP. Therefore, we only use Equation (6) without the time trend and Narayan and Popp (2010) call this M0 in their study. Narayan and Popp (2013) have shown that their test has both better size and higher power than those of LP and LS, and identify the structural breaks accurately.

breaks. We find that most of the East Asian countries have two breaks. Looking at the estimated break points we realize that most of these dates are associated with some major events and more than half of these dates are located in 1997 and 1998. In these two year, most countries in the Asian group unanimously protrudes with a large spike associated with the 1997-98 and have experienced a structural change due to the Asian financial crisis. Visual inspection of our real interest rate differential series, we can clearly observe structural shifts in the trend of the data. Accordingly, it appears sensible to allow for structural breaks in testing for a unit root. Apparently, the NP test provided evidence favouring the long-run validity of the RIRP for the six East Asian transition countries being studied.

<Table 2 is inserted about here>

The unit-root test with two endogenous breaks of the real interest rate convergence employed in this study provide some evidence favoring the long-run validity of RIRP for the East Asian countries being studied. The major policy implication that emerges from this study is that RIRP can be used to determine the equilibrium real interest rate convergence for these ten East Asian countries and regions. Our findings are consistent with Mark (1985) that we can use RIRP to test whether national real interest rates were bound to converge, the scope for international portfolio diversification would be significantly reduced; and national monetary policy as a tool of effective macro-management would be restricted to the degree it affects the international real interest rate. The implication of RIRP holds that assets of these East Asian countries with identical risk, liquidity and maturity characteristics offer the same expected return across different countries. The extent to which RIRP holds therefore serves as indicator of the degree of product and financial market integration. This might be important for several reasons and ever since Grubel (1968) it has been well known that diversifying a portfolio along international lines might improve the portfolio’s risk-return characteristics. If all other things are equal, international portfolio diversification in East Asian countries will be most attractive to investors when there are differences in real rates of interest across countries. The validity of RIRP is important to policy makers in East Asian countries who base their determination on interest rate adjustments relative to China. The findings of this study suggest that East Asian countries are highly integrated with China as leading financial center in this region. The evidence shows financial integration in the East Asian region respect to China, in complement to the findings of goods and services markets integration in most of the economies.

4. Conclusion

In this empirical study, we apply Narayan and Popp's (2010) unit root test with two endogenous breaks to assess the non-stationary properties of the real interest rate for ten East Asian countries. The test has higher power than the other unit root tests with two breaks. This study examined the validity of RIRP and the findings provide robust empirical evidence supporting the validity of the long-run RIRP, suggesting that the real interest rate adjustment of six countries these six countries is mean reversion towards RIRP equilibrium values with two structural breaks. It implies that transaction costs may affect the portfolio decisions of the international investors. This might offer an alternative explanation for the difficulty researchers have encountered in rejecting the unit root hypothesis for real interest rate convergence.

REFERENCES

Anoruo, E., Ramchander, S. and Thiewe, F. H. (2002) International linkage of interest rates evidence from the emerging economies of Asia, *Global Finance Journal,* **13**, 217-35.

Baharumshah, A. Z, Haw, C. T. and Fountas, S. (2005) A panel study on real interest rate parity in East Asian countries: pre and post-liberalization era, *Global Finance Journal*, **16(1)**, 69-85.

Cuestas, J. C. and Harrison, B. (2010) Further evidence on the Real Interest Rate Parity hypothesis in Central and Eastern European Countries: unit roots and nonlinearities, *Emerging Markets Finance and Trade,* **46(6)**, 22-39.

Dickey, D. A. and Fuller, W. A. (1981) Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, **49**, 1057-72.

Ferreira, A. L. and Le´on-Ledesma, M. A. (2007) Does the real interest parity hypothesis hold? Evidence for developed and emerging markets, *Journal of International Money and Finance*, **26**, 364-82.

Frankel, J. A. (1991) Quantifying international capital mobility, in *National Saving and Economic Performance* (Eds) D. Bernheim and J. B. Shoven, University of Chicago, 227-60.

Fraser, P. and Taylor, M. P. (1990) Some efficient tests of international real interest rate parity, *Applied Economics*, **22**, 1083-92.

Grubel, H. G. (1968) Internationally diversified portfolios: welfare gains and capital flows, *American Economic Review*, **58**, 1299-314.

Holmes, M. J. (2002) Does long-run real interest rate parity hold among EU countries? Some new panel data evidence, *The Quarterly Review of Economics and Finance*, **42**, 733-46.

Kapetanios, G. (2005) Unit-root Testing against the Alternative Hypothesis of up to m Structural Breaks, *Journal of Time Series Analysis*, **26(1)**, 123-33.

Kwiatkowski, D., Phillips, P.C.B., Schmidt, P. and Shin, Y. (1992) Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root, *Journal of Econometrics*, **54**, 159-78.

Lee, J. and Strazicich, M. (2001) Break Point Estimation and Spurious Rejectins with Endogenous Unit Root Tests, *Oxford Bulletin of Economic Statistics,* **63(5)**, 535-58.

Lee, J. and Strazicich, M. (2003) Minimum Lagrange Multiplier Unit Root Test with Two Structural Breaks, *Review of Economics and Statistics,* **85(4)**, 1082-89.

Lumsdaine, R. and Papell, D. (1997) Multiple Trend Break and the Unit-root Hypothesis, *Review of Economics and Statistics,* **79**, 212-18.

Mark, N. C. (1985) Some evidence on the international equality of real interest rates, *Journal of International Money and Finance*, **4**, 189-208.

Mark, N. C. and Moh, Y. K. (2005) The real exchange rate and real interest differentials: The role of nonlinearities, *International Journal of Finance and Economics*, **10**, 323-35.

Merlevede, B., Plasmans, J. and Aarle, B. V. (2003) A small macroeconomic model of the EU accession countries, *Open Economies Review*, **14**, 221-50.

Narayan, P. K. and Popp, S. (2010) A New Unit Root Test with Two Structural Breaks in Level and Slope at Unknown Time, *Journal of Applied Statistics*, **37(9)**, 1425-38.

Narayan, P. K. and Popp, S. (2013) Size and Power Properties of Structural Break Unit Root Tests, *Applied Economics*, **45(6)**, 721-28.

Newey, W. K. and West, K. D. (1987) A simple positive definite heteroskedasticity and autocorrelation consistent covariance matrix, *Econometrica*, **55**, 703-08.

Obstfeld, M. and Rogoff, K. (1995) Exchange rate dynamics Redux, *Journal of Political Economy*, **103**, 624-60.

Peel, D. A. and Venetis, I. A. (2005) Smooth transition models and arbitrage consistency, *Economica*, **72**, 413-30.

Perron, P. (1989) The Great Crash, the Oil Price Shock and the Unit Root Hypothesis, *Econometrica*, **57**, 1361-401

Perron, P. (1997) Further evidence on breaking trend functions in macroeconomic variables, *Journal of Econometrics*, **80(2)**, 355-85.

Phillips, P. C. B. and Perron, P (1988) Testing for a Unit Root in Time Series Regression, *Biometrika*, **75**, 335-46.

Phylaktis, K. (1999) Capital market integration in the Pacific Basin region: an impulse response analysis, *Journal of International Money and Finance*, **18**, 267-87.

Pipatchaipoom, O. and Norrbin, S. C. (2010) Is the real interest rate parity condition affected by the method of calculating the real interest rates? *Applied Economics*, **42**, 1771-82.

Popp, S. (2008) New Innovational Outlier Unit Root Test with a Beak at an Unknown Time, *Journal of Statistical Computation and Simulation*, **78(12)**, 1143-59.

Schmidt, P. and Phillips, P. (1992) LM Tests for a Unit Root in the Presence of Deterministic Trends, *Oxford Bulletin of Economic and Statistics,* **54(3)**, 257-87.

Taylor, M. P. and Sarno, L. (2004) International real interest rate differentials, purchasing power parity and the behaviour of real exchange rates: The resolution of a conundrum, *International Journal of Finance and Economics*, **9**, 15-23.

Zivot, E. and Andrews, D. (1992) Further Evidence on the Great Crash, the Oil-price Shock, and the Unit-root Hypothesis, *Journal of Business, Economics and Statistics,* **10(3)**, 251-70.

Table 1. Univariate unit root tests (with constant)

Country	Levels			First Differences		
	ADF	PP	KPSS	ADF	PP	KPSS
Hong Kong	-2.340(1)	-2.218[6]	0.446[11]*	-18.529(0)***	-18.407[5]***	0.063[4]
Indonesia	-2.140(0)	-2.161[5]	0.514[10]**	-13.019(1)***	-16.255[0]***	0.025[3]
Japan	-2.169(0)	-2.373[8]	0.428[11]*	-7.485(1)***	-12.963[7]***	0.259[8]
Korea	-2.123(0)	-2.304[6]	0.766[11]***	-13.428(0)***	-13.619[5]***	0.136[6]
Malaysia	-2.301(0)	-2.352[3]	0.388[11]*	-14.689(0)***	-14.687[2]***	0.208[2]
Mongolia	-2.282(3)	-2.562[6]	0.934[11]***	-17.224(0)***	-16.959[6]***	0.062[5]
Philippine	-3.596(0)***	-3.296[5]**	0.291[11]	-8.382(2)***	-19.195[4]***	0.092[14]
Singapore	-1.582(0)	-1.614[4]	0.482[11]**	-13.875(0)***	-13.939[4]***	0.220[4]
Taiwan	-2.641(0)*	-2.656[3]*	0.314[11]	-14.338(0)***	-14.346[2]***	0.334[3]
Thailand	-1.690(1)	-1.564[2]	0.646[11]**	-18.933(0)***	-18.542[3]***	0.153[1]

Note: ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively. The number in parenthesis indicates the lag order selected based on the recursive *t*-statistic, as suggested by Perron (1989). The number in the brackets indicates the truncation for the Bartlett Kernel, as suggested by the Newey-West test (1987).

Table 2. Test statistics of unit root tests with structural breaks (M0)

$$r_t = \rho r_{t-1} + \alpha_1^* + \beta_1^* t + \delta_1 DU'_{1,t-1} + \delta_2 DU'_{2,t-1} + \theta_1 D(T'_B)_{1,t} + \theta_2 D(T'_B)_{2,t} + \sum_{j=1}^{k} \beta_j \Delta r_{t-j} + e_t$$

	Hong Kong	Indonesia	Japan	Korea	Malaysia	Mongolia	Philippine	Singapore	Taiwan	Thailand
k	4	5	2	3	0	0	5	0	0	5
tb1	1998.07	1997.07	1998.03	1998.01	1997.07	1997.12	1997.06	1998.02	1998.02	1997.08
tb2	1998.09	1998.11	2005.01	1998.11	1998.08	1998.02	1997.09	2007.12	1998.11	1998.02
ρ	**-0.047*****	**-0.209*****	-0.007	**-0.068***	-0.050	-0.039	**-0.139****	-0.028	**-0.031*****	**-0.112****
	(-4.702)	**(-5.831)**	(-1.485)	**(-3.925)**	(-2.514)	(-2.143)	**(-4.348)**	(-1.743)	**(-4.872)**	**(-4.657)**
α_0^*	-0.179	1.625***	-0.377***	0.622**	0.049	-0.214	0.799	-0.307***	-0.307*	0.616
	(-1.225)	(2.606)	(-2.864)	(2.359)	(0.229)	(-1.111)	(1.727)	(-2.158)	(-2.027)	(1.628)
δ_1	-12.310***	-3.623***	0.373**	-1.195***	-0.182	-5.368***	-4.552***	0.309*	-0.044	-1.802**
	(-9.505)	(-3.627)	(2.192)	(2.703)	(-0.467)	(-4.401)	(-2.957)	(1.837)	(-0.124)	(-2.339)
δ_2	12.530***	2.090*	0.022	0.551	0.146	5.539***	3.778***	-0.071	0.392	6.993
	(9.811)	(1.933)	(0.170)	(1.366)	(0.472)	(4.565)	(2.534)	(-0.444)	(1.238)	(1.350)
θ_1	11.040***	47.160***	3.952***	-5.813***	-6.163***	9.002***	9.927***	3.682***	2.714***	6.501***
	(10.770)	(14.740)	(4.857)	(-5.036)	(-5.940)	(7.366)	(4.781)	(4.190)	(3.067)	()3.885
θ_2	16.010***	-29.960***	2.311***	4.978***	-2.567***	7.806***	19.730***	-3.605***	2.914***	6.050***

	(7.312)	(-8.546)	(2.918)	(4.311)	(-2.415)	(4.576)	(7.451)	(-3.557)	(3.189)	(3.400)
β_1	0.105	-0.007	0.139**	0.066			-0.059			-0.089
	(1.518)	(-0.147)	(2.148)	(1.022)			(-0.993)			(1.308)
β_2	0.057	-0.125***	0.158***	0.223***			-0.041			0.162***
	(0.969)	(-2.627)	(2.430)	(3.402)			(-0.664)			(2.416)
β_3	0.001	0.099**		0.188///			0.112*			0.074
	(0.016)	(2.092)		(2.987)			(1.833)			(1.054)
β_4	0.105**	0.037					-0.024			-0.025
	(2.224)	(0.835)					()-0.407			(0.358)
β_5		0.164***					0.112*			0.137
		(3.745)					(1.989)			(1.988)

Notes: ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively. The number in parenthesis indicates the *t*-statistic.