Abstract: This paper uses the momentum threshold autoregressive (MTAR) model and the residuals augmented Dickey-Fuller approach to test for the presence of Evans’ (1991) periodically collapsing bubbles in the domestic REIT markets. The RADF test shows evidence of bubbles, but the results of the MTAR test are mixed. The MTAR test shows asymmetric adjustment for each REIT market, but only mortgage REITs show evidence of bubbles, which turn out to be negative meaning the price falls substantially below the level warranted by fundamentals.
1. Introduction

The existence of speculative bubbles, when stock prices deviate from the level suggested by market fundamentals, does not necessarily violate the rational expectations and efficient markets hypotheses. Investors cognizant of market overvaluation are compensated for the risk of the bubble collapsing with excess positive returns. Within the literature cointegration between prices and dividends is often taken to be evidence against the presence of bubbles. However, Evans (1991) develops a class of periodically collapsing bubbles, which might escape detection by such tests. The present paper extends the empirical literature on the detection of periodically collapsing bubbles by examining four classifications of real estate investment trusts (REITs).

As discussed by Jirasakuldech et al (2005), the REIT market serves as an interesting case for examining the possibility of speculative bubbles due to market liquidity issues, informational asymmetries, and market inefficiency. First, unlike the stock market, the REIT markets do not provide enough liquidity to support short selling which often occurs when asset prices increase beyond the asset’s fundamental value (Li and Yung, 2004). Second, the presence of informational asymmetries and market inefficiency generates an under-pricing of REIT seasoned equity offerings, limiting the ability to capture market overvaluation (Ghosh et al, 2000).

tests of equity REIT returns and macro fundamentals. Jirasakuldech et al (2005) find that indeed that equity REIT prices and the macro fundamentals are cointegrated, evidence against the presence of bubbles.

However, Evans (1991) points out that the Diba and Grossman approach is unable to detect a class of rational bubbles, known as periodically collapsing bubbles. For instance, the collapse of a bubble may be interpreted as mean reversion in asset prices within the standard cointegration framework which would induce a bias towards rejection of the null hypothesis of no cointegration. More specifically, the Diba and Grossman approach to bubble detection assumes the bubble component follows a linear process whereas Evans (1991) argues that the bubble component may follow a non-linear process. Payne and Waters (2005 a, b) explore the possibility of periodically collapsing bubbles a la Evans (1991) with mixed results. In the case of the equity REIT market, Payne and Waters (2005b) find mixed evidence of positive periodically collapsing bubbles.

This study extends the literature on bubble detection in the REIT market in the following ways. First, the Diba and Grossman approach of using unit root and cointegration tests within the context of the dividend discount model is examined for the following REIT classifications: all, equity, mortgage, and hybrid REITs. Second, unlike Payne and Waters (2005a,b), the econometric approach will allow for either negative, when the price falls below the level warranted by dividends, or positive periodically collapsing bubbles. Two alternative methodologies will be used to test for periodically collapsing bubbles.

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1 In the case of REITs, Payne and Zuehlke (2005) present evidence of positive duration dependence except in the case of mortgage REIT expansions.

2 Payne and Waters (2005a) restrict their analysis to testing for negative periodically collapsing bubbles and find evidence of such bubbles in the case of mortgage and hybrid REITs. As an extension to the study by Jirasakuldech et al (2005), Payne and Waters (2005b) follow the literature by restricting their analysis in testing for positive periodically collapsing bubbles in the equity REIT market with inconclusive results.

Section 2 provides the theoretical framework for the empirical analysis. Section 3 presents the empirical methodology, the data and empirical results. Concluding remarks are presented in Section 4.

2. Theoretical Framework of Periodically Collapsing Bubbles

Let the asset price \( P_t \) at time \( t \) depend on the expectation at time \( t \) of next period’s price \( P_{t+1} \) and dividend \( D_t \) such that

\[
P_t = (1 + r)^{-1} E_t (P_{t+1} + D_{t+1})
\]

(1)

where the discount factor \( 0 < (1 + r)^{-1} < 1 \) with the general solution to (1) given as follows:

\[
P_t = \sum_{j=1}^{\infty} (1 + r)^{-j} E_t D_{t+j} + B_t.
\]

(2)

The rational bubble term \( B_t \) must satisfy the submartingale property \( E_t B_{t+1} = (1 + r)B_t \) and if a transversality condition is imposed on (2), the bubble term is \( B_t = 0 \). Indeed, if these conditions hold, the asset price \( P_t \) is determined solely by expected future dividends.

While some question the existence of bubbles in light of the conditions mentioned above, there has been considerable research on whether asset prices are determined by dividends alone. Specifically, Diba and Grossman (1988a) argue that the existence of cointegration between \( P_t \) and \( D_t \) does not lend support for the existence of bubbles.

\[\textsuperscript{3}\] The theoretical section draws heavily from Payne and Waters (2005 a, b). However, unlike Payne and Waters (2005 a, b), there is no restriction as to the whether a bubble can be negative or positive.
However, Evans (1991) questions the approach undertaken by Diba and Grossman (1988a) in that a class of bubbles, known as periodically collapsing bubbles, may very well exist that would not be detected by simple cointegration techniques. Recognizing the issue raised by Evans (1991), we modify his model to allow for the possibility of positive and negative periodically collapsing bubbles as follows:

\[ B_{t+1} = (1 + r)B_t \gamma_{t+1}, \quad \text{if } |B_t| \leq \alpha \]  

\[ B_{t+1} = [\delta + (1 + r) \pi^{-1} \theta_{t+1} (B_t - (1 + r)^{-1} \delta)] \gamma_{t+1}, \quad \text{if } |B_t| > \alpha. \]  

The parameters in equations (3a) and (3b) satisfy \( \delta, \alpha > 0 \) and \( 0 < \delta < (1 + r) \alpha. \) The stochastic process \( \gamma_t \) is iid, has conditional expectation \( E\gamma_{t+1} = 1, \) and \( \gamma_t > 0, \) which ensures that a bubble will not switch sign. The term \( \theta_t \) represents a Bernoulli process that takes the value 1 with probability \( \pi \) and the value 0 with probability \( 1 - \pi. \) Equation (3a) represents the phase when the bubble grows at mean rate \( 1 + r \) but equation (3b) shows that if the bubble exceeds the threshold \( \alpha, \) it explodes at mean rate \( (1 + r) \pi^{-1}. \) However, this phase does not last indefinitely as the bubble collapses with probability \( 1 - \pi \) each period.

The non-linearity of the process in equations (3a) and (3b) creates difficulties in detecting such bubbles via standard cointegration tests between prices and dividends. Whether the bubble term \( B_t \) is positive or negative depends solely on the initial value \( B_{t0}. \) If a bubble is negative, meaning the prices fell severely below the long term trend for dividends, it will always be negative and similarly for positive bubbles.

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4 Charemza and Deadmen (1995) specify a more general model of periodically collapsing bubbles.
Many authors such as Diba and Grossman (1988b) have postulated the impossibility of negative bubbles, reasoning that they would eventually lead to negative prices. In contrast, Weil (1990) constructs a general equilibrium model showing the possibility of negative bubbles. He shows that if the presence of a bubble alters traders discount rate, their valuation of fundamentals could fall leading to a fall in the asset price. Since the econometrician does not observe these changes, the falling price appears as a negative bubble. We find it quite plausible that traders would focus more on short term gains during a bubble episode and allow for the possibility of either positive or negative bubbles for the empirical tests in this paper.

3. Methodology, Data, and Results

Monthly data on the prices and dividends for all, equity, mortgage, and hybrid REITs were obtained from the National Association of Real Estate Investment Trusts (NAREIT) for the period 1972:01 to 2005:9. The original data was deflated by the consumer price index and converted to natural logarithms. The empirical work begins by testing the null hypothesis of a unit root in the respective real REIT prices, \( p_i^t \), and real REIT dividends, \( d_i^t \), where superscript \( i \) denotes the specific REIT market: \( a \) (all), \( e \) (equity), \( m \) (mortgage), and \( h \) (hybrid), incorporating the possibility of structural breaks using Perron’s (1989) unit root test.

\[
y_t = \mu + \theta DU + \beta t + \gamma DT + \delta D(T_b) + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \epsilon_t
\]  

(4)

where \( y_t = p_i^t \) or \( d_i^t \); \( DU = 1(t > T_b) \) is a post-break constant dummy variable; \( t \) is a linear time trend; \( DT = 1(t > T_b) t \) is a post-break slope dummy variable;
$D(T_n) = 1(t = T_n + 1)$ is the break dummy variable; and $\varepsilon_t$ are white noise error terms. The null hypothesis of a unit root is given by $\alpha = 1$.

Jirasakuldech et al (2005) provide several arguments in exogenously imposing a structural break in 1991:11. First, there was increased market liquidity in the post-1992 period as the REIT market became dominated by large institutional investors (Chan et al, 2003). Second, there was greater market transparency of the REIT market given the increased analyst and media coverage of the markets (Gentry et al, 2003 and Chui et al, 2003). Third, in 1991 the umbrella partnership REIT organization structure was created, which permitted greater flexibility in purchasing property; however, valuation become more difficult given the lack of transparency (Damodaran et al, 1997 and Ling and Ryngaert, 1997).

Table 1 reports the results of the unit root tests allowing for an exogenously structural break in 1991:11. The results across the REIT classifications indicate that real prices and dividends are indeed integrated of order one. Given the respective prices and dividends are integrated of the same order, the Diba and Grossman approach to bubble detection is examined by specifying the following cointegration equation representing the relationship between REIT prices, $p_t$, and dividends, $d_t$.

$$p_t^i = \alpha + \beta d_t^i + \varepsilon_t$$

As reported in Panel A of Table 2 (column CR) prices and dividends appear cointegrated in each case as evident from the significant ADF test statistic. Following the methodology of Diba and Grossman, the presence of a cointegrated relationship between prices and dividends can be interpreted as evidence against the presence of speculative bubbles in the REIT market. However, interpreting the presence of cointegration
between price and dividends as evidence against bubbles assumes a linear process for the growth of $B_t$, which implies normality in the residuals. This interpretation is questionable given that a preliminary examination of the residuals from equation (4) displays both skewness and excess kurtosis in the residuals, suggesting the presence of periodically collapsing bubbles (see Panel A of Table 2).

Taylor and Peel (1998) incorporate skewness and excess kurtosis in constructing a more efficient estimator in cointegration tests of bubbles. Specifically, tests of cointegration examine the stationarity of the residuals from equation (4) as follows:

$$
\Delta \hat{e}_t = \psi \hat{e}_{t-1} + u_t
$$

where the null hypothesis of no cointegration is $\psi = 0$ while the alternative hypothesis is a stationary residual, $\psi < 0$. As pointed out by Taylor and Peel (1998), a more efficient estimator of $\psi$ can be obtained by correcting the least squares estimate in equation (5) for skewness and excess kurtosis which will improve the ability to detect periodically collapsing bubbles. Moreover, the adjustment for skewness and excess kurtosis has superior power over standard cointegration tests to correctly reject a mean-reverting error model as a bubble.

Taylor and Peel (1998) advocate the following two-step estimator in the construction of the residuals-augmented Dickey-Fuller (RADF) test of the null hypothesis of no cointegration. First, regress the first difference of the residuals of the cointegrating equation on their lagged level (see equation 5 above) and use the new residuals, $\hat{u}_t$, and

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5 This test is based on the work of Im (1996) with respect to residuals-augmented least squares estimators.

6 Taylor and Peel (1998), Sarno and Taylor (1999, 2003), as well as Capelle-Blancard and Raymond (2004) construct critical values and analyze the power of this test against alternatives.
the estimated variance, \( \hat{\sigma}^2 \), to construct the vector, \( \hat{\nu}_t = [(\hat{u}_t^3 - 3\hat{\sigma}^2\hat{u}_t), (\hat{u}_t^2 - \hat{\sigma}^2)] \).

Second, re-estimate equation (5) with the addition of the vector, \( \hat{\nu}_t \), which corrects the estimate of \( \psi \) for skewness and excess kurtosis of the residuals as follows:

\[
\Delta \epsilon_t = \psi \epsilon_{t-1} + \varphi \hat{\nu}_t + \nu_t
\]

where \( \nu_t \) is white noise. The key test statistic is, \( CR_t = \hat{\psi}^* / \sqrt{V(\hat{\psi}^*)} \), where \( \hat{\psi}^* \) is the estimator in equation (6).\(^7\) Panel A of Table 2 reports the results of the RADF test (column CR\(_t\)) for each of the REITs. The RADF test cannot reject the null hypothesis of non-cointegration for any of the REITs, thus providing evidence of bubble-like behavior.

While the RADF test suggests the possibility of bubbles in the respective REIT markets, the MTAR model proposed by Enders and Siklos (2001) is estimated to determine the possible asymmetries in the adjustment towards the long-run equilibrium relationship between REIT prices and dividends, i.e. the dynamics of periodically collapsing bubbles.\(^8\) The possibility of asymmetric adjustment is undertaken in the following regression of the residuals generated from equation (4).

\[
\Delta \hat{\epsilon}_t = I_t \rho_1 \hat{\epsilon}_{t-1} + (1-I_t) \rho_2 \hat{\epsilon}_{t-1} + \sum_{i=1}^\rho \gamma_i \Delta \hat{\epsilon}_{t-i} + \nu_t
\]

with the Heaviside indicator function, \( I_t \), represented by:

\[^7\text{The covariance matrix of } \hat{\psi}^* \text{ is estimated by } V(\hat{\psi}^*) = \sigma^2_A (\tilde{X}' \hat{M}_{\tilde{\psi}} \tilde{X})^{-1} \text{ where}
\]

\[
\sigma^2_A = \sigma^2 - \frac{\mu^2_5 (\mu_6 - 6\mu_4 \sigma^2 + 9\sigma^6 - \mu_3^2) - 2\mu_3 (\mu_4 - 3\sigma^4)(\mu_5 - 4\mu_3 \sigma^2) + (\mu_4 - 3\sigma^4)^2 (\mu_4 - \sigma^4)}{(\mu_4 - \sigma^4)(\mu_6 - 6\mu_4 \sigma^2 + 9\sigma^6 - \mu_3^2) - (\mu_5 - 4\mu_3 \sigma^2)^2}
\]

and \( \mu_i \) denotes the \( i^{th} \) central moment of \( \epsilon_t \). \( \tilde{X} \) is the vector of the lagged series of centered residuals and the idempotent matrix, \( \hat{M}_{\tilde{\psi}} \), is given by \( \hat{M}_{\tilde{\psi}} = I_T - \tilde{W}'(\tilde{W}'\tilde{W})^{-1}\tilde{W} \) where \( I_T \) is the identity matrix and \( \tilde{W} \) is the matrix of the centered residuals of \( \hat{\epsilon}_t \).

\[^8\text{Bohl (2003) uses the MTAR model with U.S. stock market data.}\]
\[ I_t = \begin{cases} 1 & \text{if} \quad \Delta \hat{\varepsilon}_{t-1} \geq \tau \\ 0 & \text{if} \quad \Delta \hat{\varepsilon}_{t-1} < \tau \end{cases} \quad (8) \]

where the threshold \( \tau \) value is set in accordance with minimization of the residual sum of squares.\(^9\) The MTAR model allows the adjustment to depend on the previous period’s change in \( \hat{\varepsilon}_{t-1} \). The MTAR model is especially valuable when the adjustment is believed to exhibit more momentum in one direction than the other. The null hypothesis of no cointegration is tested by the restriction, \( \rho = \rho_2 = 0 \). If real REIT prices, \( p_t^i \), and dividends, \( d_t^i \), are cointegrated, the null hypothesis of symmetry is tested by the restriction, \( \rho_1 = \rho_2 \). Indeed, if the estimated coefficient, \( \rho \), is statistically significant and negative and larger in absolute terms relative to the estimated coefficient, \( \rho_2 \), the null hypothesis of symmetric adjustment is rejected which would provide evidence in favor of Evans’ (1991) definition of positive periodically collapsing bubbles in REIT prices. On the other hand, if the estimated coefficient, \( \rho_1 \), is statistically significant and negative and smaller in absolute terms relative to the estimated coefficient, \( \rho_2 \), the null hypothesis of symmetric adjustment is rejected which would provide evidence in favor of Evans’ (1991) definition of negative periodically collapsing bubbles in REIT prices.

Panel B of Table 2 displays the results of the MTAR models. Note from equations (7) and (8), the MTAR specification provides point estimates of \( \rho \) and \( \rho_2 \). First, the point estimates, \( \rho_1 \) and \( \rho_2 \), satisfying the stationarity (convergence) conditions. The null

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\(^9\) Chan (1993) requires sorting the estimated residuals in ascending order, eliminating 15 percent of the largest and smallest values. The threshold parameter that yields the lowest sum of squared errors from the remaining 70 percent of the residuals is used in the MTAR model. We found similar results using 10 and 5 percent cutoffs.
hypothesis of no cointegration, \( \rho_1 = \rho_2 = 0 \), (FC column) is rejected for each type of REIT. Furthermore, the null hypothesis of symmetry, \( \rho_1 = \rho_2 \), is rejected in each case with the exception of hybrid REITs which displays symmetric adjustment. However, upon closer inspection of the various REITs, it appears that \( \rho_1 \) is positive and statistically insignificant in the cases of all and equity REITs, suggesting the absence of a periodically collapsing bubble. The equity REIT results confirm earlier results reported by Payne and Waters (2005a,b) over a slightly different time frame. With respect to mortgage REITs, the estimated coefficient, \( \rho_1 \), is statistically significant and negative and smaller in absolute terms relative to the estimated coefficient, \( \rho_2 \), indicative of negative periodically collapsing bubbles, a similar result to Payne and Waters (2005a). Contrary to Payne and Waters (2005a), who find evidence of a negative bubble in hybrid REITs, the results reported in this study do not support the presence of either positive or negative periodically collapsing bubbles.

4. Concluding Remarks

This study has extended the recent work of Jirasakuldech et al (2005) as well as Payne and Waters (2005a,b) on bubble detection in the REIT market in the following ways. First, the Diba and Grossman approach of using unit root and cointegration tests within the context of the dividend discount model is examined for the following REIT classifications: all, equity, mortgage, and hybrid REITs. Second, unlike Payne and Waters (2005a,b), the econometric approach will allow for either negative or positive periodically collapsing bubbles. Within the cointegration framework for testing for speculative bubbles, Diba and Grossman (1988) argue that such bubbles do not exist if
prices and dividends are cointegrated. The Diba and Grossman approach implicitly assumes the bubble component follows a linear process whereas the bubble component may very well follow a nonlinear process, known as a periodically collapsing bubble (Evans, 1991).

Two alternative econometric approaches are used to tests for the presence of Evans’ (1991) periodically collapsing bubbles. First, the residuals-augmented Dickey-Fuller (RADF) model incorporates skewness and excess kurtosis in providing a more efficient estimator in cointegration tests of bubbles. Contrary to the standard cointegration tests, the results of the RADF tests are unable to reject the null hypothesis of non-cointegration for each REIT classification. Second, in order to capture the asymmetric adjustment processes associated with either negative or positive periodically collapsing bubbles, the momentum threshold autoregressive (MTAR) model is estimated for each REIT classification. The MTAR results indicate the absence of periodically collapsing bubbles for all, equity, and hybrid REIT classifications; however, mortgage REITs exhibit behavior indicative of negative periodically collapsing bubbles.
<table>
<thead>
<tr>
<th>Panel</th>
<th>Type</th>
<th>Test Statistic</th>
<th>Critical Value</th>
<th>Probability Value</th>
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</thead>
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<tr>
<td>A</td>
<td>Real All REITs</td>
<td>( p_i^a )</td>
<td>-2.44</td>
<td>-1.50</td>
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<td></td>
<td></td>
<td>( \Delta p_i^a )</td>
<td>-18.60</td>
<td>-16.67</td>
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<td>B</td>
<td>Equity REITs</td>
<td>( p_i^e )</td>
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<td>-2.26</td>
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<td></td>
<td></td>
<td>( \Delta p_i^e )</td>
<td>-18.40</td>
<td>-10.00</td>
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<td>C</td>
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<td>( p_i^m )</td>
<td>-2.76</td>
<td>-3.08</td>
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<tr>
<td></td>
<td></td>
<td>( \Delta p_i^m )</td>
<td>-12.93</td>
<td>-7.04</td>
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<tr>
<td>D</td>
<td>Hybrid REITs</td>
<td>( p_i^h )</td>
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Notes: Standard errors are denoted in parentheses and probability values in brackets. Critical values to test the null hypothesis of a unit root, \( \alpha = 1 \) from equation (4) is drawn from Table VI.B p. 1377 of Perron (1989) for \( \lambda = .60 \) as follows: 1% -4.88, 5% -4.24, and 10% -3.95.
Table 2
MTAR and RADF Results
1972:1 to 2005:9

Panel A: Residuals –Augmented Dickey-Fuller Results

<table>
<thead>
<tr>
<th></th>
<th>CR</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>CR_t</th>
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<tr>
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<td>6.78</td>
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<td>-0.59</td>
<td>31.57</td>
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<tr>
<td>Mortgage</td>
<td>-4.34^a</td>
<td>0.27</td>
<td>3.80</td>
<td>-1.92</td>
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<tr>
<td>Hybrid</td>
<td>-3.45^b</td>
<td>0.80</td>
<td>5.00</td>
<td>-1.12</td>
</tr>
</tbody>
</table>

Panel B: Momentum Threshold Autoregressive Model Results

<table>
<thead>
<tr>
<th></th>
<th>(\tau)</th>
<th>(\rho_1)</th>
<th>(\rho_2)</th>
<th>(F_C)</th>
<th>(F_A)</th>
<th>Q(5)</th>
<th>(k)</th>
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<tbody>
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<td>All</td>
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<td>5.60^a</td>
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<td></td>
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<td></td>
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<td>0.02</td>
<td>-0.07</td>
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<td>Mortgage</td>
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<td>8.59^a</td>
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<td></td>
<td>(-2.16)^b</td>
<td>(-4.62)^a</td>
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<tr>
<td>Hybrid</td>
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<td>-0.06</td>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>

Notes: CR is the Dickey-Fuller test statistic applied to the residuals from the cointegration equation (4) under the null hypothesis of no cointegration with critical values: a(1%) -3.73, b(5%) -3.17, and c(10%) -2.91 (Engle and Granger, 1987). CR_t is the residuals-augmented Dickey-Fuller test statistic applied to the residuals from the cointegrating equation (4) under the null hypothesis of no cointegration with critical values: a(1%) -3.98, b(5%) -3.44, and c(10%) -3.13 (Capelle-Blancard and Raymond, 2004). \(\tau\) is the estimated threshold. \(\rho_1\) and \(\rho_2\) are the estimated parameters from the MTAR specification. t-statistics denoted by ( ), and probability values in { } where a(1%), b(5%), and b(10%). \(F_C\) represents the F-statistic corresponding to the null hypothesis of no cointegration (i.e. \(\rho_1 = \rho_2 = 0\)) with critical values provided by Enders and Siklos (2001, Table 5, p. 172, n = 250 and four lags an one lag which are denoted in brackets): a(1%) 8.47 [8.84], b(5%) 6.32 [6.63], and c(10%) 5.32 [5.57]. \(F_A\) represents the F-statistic corresponding to the null hypothesis of symmetry (i.e. \(\rho_1 = \rho_2\)) using the standard F distribution with critical values a(1%) 4.61 and b(5%) 3.00. \(k\) is the number of lags in equation (7). Q(5) denotes the Ljung-Box Q-statistic at 5 lags.
References


