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Is Malaysian Stock Market Efficient? Evidence from Threshold Unit Root Tests

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Abstract

This paper investigates the behavior of Kuala Lumpur Stock Exchange Composite Index (KLCI) for the period from 1980:1 to 2008:8 using a two-regime threshold autoregressive (TAR) model with an autoregressive unit root developed by Caner and Hansen [Threshold autoregression with a unit roots, Econometrics 69 (6) (2001) 1555-1596] which allows testing nonlinearity and nonstationarity simultaneously. Our finding indicates that the KLCI is a nonlinear series that is characterized by a unit root process, consistent with the efficient market hypothesis.

We are grateful to Bruce Hansen for making available his Gauss Programme to estimate and make inferences on the TAR model. The usual disclaimer applies.
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1. Introduction

The stock market efficiency hypothesis is among the most popular research topic in the international macroeconomic literature. Stock market efficiency implies that prices respond quickly and accurately to relevant information. Information in the efficient market hypothesis is defined as anything that may affect prices which is unknowable in the present and appears randomly in the future. This random information is the cause of future price changes. In other words, an efficient stock market is characterized by a random walk (unit root) process, which indicates that stock market returns cannot be predicted based on its historical observations. If stock price follows a random walk process, any shock to stock price is permanent, and there is no tendency for the price level to return to a trend path over time. In contrast, a mean reverting process (trend stationary) means that any shock to stock price is transitory and there is tendency for the price level to return to a trend path over time. The random walk property implies that future returns are unpredictable based on previous observations and that volatility of stock price can grow without bound in the long-run. Hence, testing for mean reversion in stock prices is one avenue for examining market efficiency (see Fama and French, 1988a, 1988b).

There is a large body of the literature that investigates the efficient market hypothesis using a variety of methodology and found mixed results. Many studies have found that stock indexes are not characterized by a unit root (see Lo and MacKinlay, 1988; Poterba and Summers, 1988; Urrutia, 1995; Grieb and Reyes, 1999; Chaudhuri and Wu, 2003; Shively, 2003; Narayan, 2008), while others have found stock indexes to be a unit root process (Huber, 1997; Liu *et al*., 1997; Ozdemir, 2008; Narayan, 2005, 2006; Narayan and Smyth, 2004, 2005; Qian *et al*., 2008;). Two important features characterize these studies.

First, the majority of these studies are based on univariate unit root tests. However, one strong criticism of the univariate unit root tests, such as the Dickey and Fuller test used by the most studies, is that it lacks power if the true data generating process of a series exhibits structural breaks (Perron, 1989). Therefore, the majority of these studies adopt new developed unit root test with structural breaks (Zivot and Andrew, 1992; Lumsdaine and Papell, 1997; Lee and Strazicich, 2003; Im *et al*., 2005) to investigate the stationary property of stock prices. For example, Chaudhuri and Wu (2003) investigate mean reversion in stock prices in emerging markets, including one break unit root tests. Their findings, when compared to previous findings, show that there is no consensus among economists regarding market efficiency. Narayan and Smyth (2004) apply the Zivot and Andrews (1992) one break and the Lumsdaine and Papell (1997) two break unit root tests to examine the random walk hypothesis for stock prices in South Korea. Their results provide strong evidence that stock prices in South Korea are characterized by a unit root, which is consistent with the efficient market hypothesis. Lean and Smyth (2007) apply univariate and panel Lagrange Multiplier (LM) unit root tests with one and two structural breaks (Lee and Strazicich, 2003; Im *et al*., 2005) to examine the random walk hypothesis for stock prices in eight Asian countries. The results from the univariate LM unit root tests and panel LM unit root test with one structural break suggest that stock prices in each country is characterized by a random walk, but the findings from the panel LM unit root test with two structural breaks suggest that stock prices in the eight countries are mean reverting. Narayan (2008) provide evidence on the unit root hypothesis for G7 stock price indices using the Lagrangian multiplier (LM) panel unit root test that allows for structural breaks. His main finding is that stock prices are stationary processes, inconsistent with the efficient market hypothesis.

Second, however, following the work of (Abhyankar *et al*., 1995, 1997; Atchison and White, 1996; Kohers *et al*., 1997; Schaller and van Norden, 1997; Qi, 1999; Kanas, 2001; Sarantis, 2001; Shively, 2003; Narayan, 2005, 2006; Qian *et al*., 2008; among others), who find stock prices to be consistent with a nonlinear data generating process, the reliability of the findings from existing studies is questionable. Shively (2003) examines the six stock prices (CAC 40, DAX 30, FTSE 100, Nikkei 225, S&P 500 and TSE 300) for the period 1970:1-2000:12. He applies Tsay's (1998) chi-squared test and find that all six stock-price indexes are all highly consistent with threshold nonlinearity. Then he applies Tsay's (1998) threshold modeling technique to partition each stock-price index into three regimes using the corresponding stock-return series as the stationary threshold variable and finds the series to be a regime reverting process. This nonlinear regime-reverting process implies a violation of the efficient market hypothesis. In contrast, Narayan (2006) investigates the behavior of US stock prices using an unrestricted two-regime threshold model for the period1964:06 to 2003:04. He finds that the stock prices are nonlinear process and characterized by a unit root process, consistent with the efficient market hypothesis.

Lean and Symth (2007) suggest that, in terms of future research, there is growing evidence that univariate unit root tests lack the power to find mean reversion in stock prices. Perhaps a more promising approach might be to examine whether Asian stock prices are nonlinear with a unit root. Thus, this paper contributes to the existing literature on the random walk hypothesis, by providing additional evidence on the Malaysian stock market efficiency, using the threshold autoregressive (TAR) model developed by Caner and Hansen (2001). Caner and Hansen methodology is applicable if a nonlinear process has unit root. The main advantage of the TAR model is that it allows us to discriminate nonstationarity from nonlinearity in data simultaneously. Furthermore, their methodology allows testing for a partial unit root process in two regimes[1]. Our main finding is that the Malaysian stock price is a nonlinear process and is characterized by unit root. The latter finding is consistent with the efficient market hypothesis.

The rest of the paper is organized as follows: Section 2 outlines the empirical methodology. Section 3 presents the data and empirical results. Finally, Section 4 provides conclusion.

2. Empirical Methodology

Following the work of Caner and Hansen (2001), we adopt a two-regime TAR (*k*) model with an autoregressive unit root as follow:

$$\Delta y_t = \theta_1' x_{t-1} I_{\{Z_{t-1} < \lambda\}} + \theta_2' x_{t-1} I_{\{Z_{t-1} \geq \lambda\}} + e_t \tag{1}$$

Where y is the logarithm of the stock price index for t = 1,. . .,T, $x_{t-1} = (y_{t-1}, r_t', \Delta y_{t-1}, ..., \Delta y_{t-k})'$; $I_{\{\bullet\}}$ is the indicator function; e_t is an independently and identically error term; $Z_t = y_t - y_{t-m}$ for

[1] Many studies (see, Alba and Park , 2005; Basci and Caner, 2005 and Ho, 2005) have applied this methodology to test the unit root and threshold effect to exchange rates and Purchasing Power Parity (PPP) .

m represents the delay order and some $1 \le m \le k$. r_t is a vector of deterministic components including an intercept and a possible linear time trend. The threshold value λ is unknown and takes the values in the compact interval $\lambda \in \Lambda = [\lambda_1, \lambda_2]$, where λ_1 and λ_2 are picked according to $P(Z_t \le \lambda_1) = \pi_1 > 0$ and $P(Z_t \le \lambda_2) = \pi_2 < 1$. It is convenient to show the components of θ_1 and θ_2 as follow:

$$\theta_1 = \begin{pmatrix} \rho_1 \\ \beta_1 \\ \alpha_1 \end{pmatrix} \quad \text{and} \quad \theta_2 = \begin{pmatrix} \rho_2 \\ \beta_2 \\ \alpha_2 \end{pmatrix} \tag{2}$$

where ρ_1 and ρ_2 are slope coefficients on y_{t-1}, β_1 and β_2 are scalar intercepts, and α_1 and α_2 are K x 1 vectors containing the slope coefficients on dynamics regressors ($\Delta y_{t-1}, \ldots, \Delta y_{t-k}$) in the two regimes. In order to calibrate equation (1), the concentrated least squares (LS) approach is usually utilized. For each $\lambda \in \Lambda$, equation (1) is estimated ordinary least square (OLS) so that

$$\Delta y_t = \hat{\theta}_1(\lambda)' x_{t-1} I_{\{Z_{t-1} < \lambda\}} + \hat{\theta}_2(\lambda)' x_{t-1} I_{\{Z_{t-1} \ge \lambda\}} + \hat{e}_t \tag{3}$$

Let $\hat{\sigma}^2(\lambda) = T^{-1} \sum_1^T \hat{e}_t(\lambda)^2$ be the OLS estimate of σ^2 for fixed λ. The LS estimate of threshold parameter (λ) is found by minimizing the residual variance, $\sigma^2(\lambda)$:

$$\hat{\lambda} = \arg\min_{\lambda \in \Lambda} \hat{\sigma}^2(\lambda) \tag{4}$$

Estimating the TAR model in equation (1), the two central issues are whether or not there is a threshold effect and whether the process y_t (stock price index) is stationary or not. In this paper standard Wald test statistics, $W_T = W_T(\hat{\lambda}) = \sup_{\lambda \in \Lambda} W_T(\lambda)$, proposed by Caner and Hansen (2001), is used to test the null hypothesis of no threshold effect (i.e., the process is linear) H_0: $\theta_1 = \theta_2$, against the alternative of threshold effect (i.e., the process is nonlinear). If the null hypothesis cannot be rejected, there is no threshold effect, in which case the two vectors of coefficients are identical between the two regimes ($\theta_1 = \theta_2$). Caner and Hansen find that W_T has a non-standard asymptotic null distribution with critical values that cannot be tabulated. Hence they propose a bootstrap method to compute asymptotic critical values and p-values.

The stationarity of the process y_t depends on the parameters ρ_1 and ρ_2. For regime 1, we can reject the null hypothesis of unit roots in favor of the alternative hypothesis of level stationarity if ρ_1 is significantly different from zero. We can do the same for regime 2 if ρ_2 is significantly different from zero. If the null hypothesis: H_0: $\rho_1 = \rho_2 = 0$ holds, the process y_t has a unit root and model (1) can be expressed in terms of the stationary difference Δy_t. The obvious alternative to H_0 is H_1: $\rho_1 < 0$ and $\rho_2 < 0$, in which case the process y_t is stationary in both regimes. We also have to consider the intermediate partial unit root case H_2: $\rho_1 < 0$ and $\rho_2 = 0$ or $\rho_1 = 0$ and $\rho_2 < 0$, in which case the process y_t have a unit root in one regime and is stationary in other showing mean reversion behavior.

The null hypothesis is tested against the unrestricted alternative $\rho_1 \neq 0$ or $\rho_2 \neq 0$ using the Wald statistics, and expressed as, $R_{2T} = t_1^2 + t_2^2$, where t_1 and t_2 are the t-ratios for $\hat{\rho}_1$ and $\hat{\rho}_2$ respectively from the OLS estimation. However, Caner and Hansen (2001) note that this two-sided Wald statistics may have less power than a one-sided version of the test. As a result, they recommend the following one-sided Wald statistics:

$$R_{1T} = t_1^2 I_{\{\hat{\rho}_1 < 0\}} + t_2^2 I_{\{\hat{\rho}_2 < 0\}} \quad (5)$$

which tests H_0 against the one-sided alternative $\rho_1 < 0$ or $\rho_2 < 0$. A statistically significant R_{1T} justifies rejecting unit roots in favor of stationarity. However, it does not allow us to discriminate between the stationary case H_1 and the partial unit root case H_2. This requires further examining the individual t statistics t_1 and t_2. Only one of $-t_1$ or $-t_2$ being significant would be consistent with the partial unit root case.

3. Data and Empirical Results

The data studied in this paper are the logged values of the KL Composite index (KLCI)[2], which is the main index for Bursa Malaysia (stock exchange). Monthly data over the period from 1980:1 to 2008:8 are utilized for analysis and taken from Bloomberg database. Specifically, we retrieve the closing prices of the last trading days of all months, which give the time series y_t defined in the preceding section.

Before beginning the tests we consider conventional Augmented Dickey Fuller (ADF) test for unit root against linear stationary alternative. The results are not reported here to conserve space but are available from the authors upon request. We find the calculated t-statistics to be –1.8976 (with an intercept) and –2.8588 (with an intercept and a trend), respectively. Given the 10% level critical value of –2.5712 (for model with no trend) and –3.1344 (for model with trend), we are unable to reject the unit root null hypothesis. This finding is not surprising since ADF test have almost no power when alternative is nonlinear process. This implies that KLCI has a unit root[3].

To examine the stationarity in the possible presence of nonlinearities, we apply the Caner and Hansen procedure described above. The first issue we must address is the presence of the threshold effects. As stated previously, the appropriate test this purpose is the standard Wald statistic W_T. in Table 1, we report the results of the Wald test, bootstrap critical values at three conventional levels 10%, 5%, and 1%, and bootstrap p-values (using 10000 replications) for threshold variables of the form $Z_t = y_t - y_{t-m}$ for different delay parameters m ranging from 1 to 12. The significant bootstrap p-values corresponding to the Wald tests W_T (except for $m = 4$, which is not statistically significant) indicate that we can reject the null hypothesis of linearity in favor of the alternative that there is a threshold effect in the monthly KLCI series. According to

[2] The Stock Exchange of Malaysia was officially formed in 1964 under the name Stock Exchange of Malaysia and Singapore (SEMS). In 1973, with the termination of currency interchangeability between Malaysia and Singapore, the SEMS was separated into The Kuala Lumpur Stock Exchange Bhd (KLSEB). KLSEB became a demutualised exchange and was re-named Bursa Malaysia in 2004 with total market capitalization of MYR700 billion (US$189 billion). As of 31 December 2007, the Malaysia Exchange had 986 listed companies with a combined market capitalization of $325 billion.

[3] Phillips and Perron (1988) and Kwiatkowski *et al*. (KPSS, 1992) unit root tests also conducted, and we found the identical results. All results are available from the author upon request.

these results, the linear AR model can be rejected in favour of the TAR model. In order to avoid the criticism that the results of Table 1 is conditional on m, which is generally unknown, Caner and Hansen (2001) recommend making m endogenous, which is achieved by selecting an m value that minimizes the residual variance of the least squares estimates. This is also the value that maximizes W_T since W_T is a monotonic function of the residual variance (Alba and Park, 2005). According to Table 1, the Wald statistics is maximized (W_T = 46.7, corresponding p-value = 0.002) when m = 5. Hence we take $\hat{m}$ = 5 as the preferred model.

Table 1. Threshold Test

m	W_T	Bootstrap critical values			Bootstrap p-values
		10%	5%	1%	
1	35.7	31.3	34.5	41.1	0.029
2	31.2	30.9	33.8	40.9	0.092
3	32.3	30.8	34.0	40.9	0.089
4	22.0	30.7	33.9	40.7	0.514
5	46.7	30.7	33.9	39.7	0.002
6	45.0	30.7	33.7	39.0	0.002
7	39.0	30.7	33.8	40.0	0.014
8	36.8	30.6	33.8	40.0	0.024
9	35.9	30.7	33.4	39.8	0.028
10	41.5	30.6	33.5	39.9	0.007
11	38.9	30.6	33.3	40.0	0.012
12	38.7	30.5	33.3	40.4	0.015

We now examine the unit root properties of the KLCI. We first calculate the one-sided and two-sided threshold unit root test statistics R_{1T} and R_{2T} along with the bootstrap critical values and p-values for each delay parameters m, ranging from 1 to 12. The results are reported in Table 2. The Wald statistic W_T obtained from R_{1T} is statistically insignificant at the 10% level for all m. For the preferred model m = 5, the W_T test statistic of 2.80 is less than the 10% critical value (9.2). We find similar results from the two-sided Wald tests R_{2T} presented in the right panel of Table 2. For all m, Wald statistics W_T are less than the bootstrap critical values at the 10% level of significance. These results suggest that the null hypothesis of the presence of a unit root in the monthly KLCI cannot be rejected at the 10% level.

Table 2. One and Two sided Unit root Tests

	R_{1T}					R_{2T}				
		Bootstrap critical values					Bootstrap critical values			
m	W_T	10%	5%	1%	*p*-values	W_T	10%	5%	1%	*p*-values
1	3.15	9.1	11.3	16.2	0.571	3.15	9.5	11.6	17.1	0.603
2	2.98	9.1	11.3	16.5	0.594	2.99	9.5	11.8	17.1	0.627
3	1.81	9.1	11.4	16.0	0.751	1.82	9.6	11.8	16.4	0.788
4	1.71	9.3	11.3	16.4	0.754	1.73	9.6	11.8	16.7	0.791
5	2.80	9.2	11.4	16.5	0.606	2.80	9.6	11.9	17.1	0.643
6	1.73	9.3	11.5	16.8	0.762	1.75	9.7	11.9	17.1	0.800
7	1.73	9.2	11.5	16.8	0.761	1.76	9.6	11.9	17.0	0.798
8	3.94	9.3	11.5	16.5	0.472	3.94	9.7	12.1	16.9	0.508
9	7.03	9.4	11.7	16.8	0.205	7.03	9.7	12.2	17.1	0.229
10	6.66	9.5	11.8	17.2	0.234	6.67	9.9	12.2	17.8	0.256
11	4.17	9.6	11.8	17.0	0.458	4.20	9.9	12.2	17.1	0.490
12	3.88	9.4	11.8	17.4	0.495	3.88	9.8	12.1	17.6	0.527

To investigate stationarity of the regimes individually, we examine the individual *t* statistics (partial unit root), t_1 and t_2. We report the *t* statistics along with the bootstrap critical values and bootstrap *p*-values in Table 3. For our preferred model $m = 5$, the t_1 statistic (0.79) is smaller than the bootstrap critical value (2.87) at the 5% level of significance. Moreover, the t_2 statistic is insignificant at the same level of significance since it is (1.47) smaller than the bootstrap critical value (2.81). So, according to the *t* statistics results, we conclude that both regimes are characterized by unit root individually. Hence, we are again unable to reject the unit root null hypothesis in both regimes of the monthly KLCI series. The tests results from R_{1T}, R_{2T}, t_1, and t_2, support the fact that the KLCI is characterized by unit root process, consistent with the efficient market hypothesis.

Table 3. Partial Unit root Tests

	t_1					t_2				
		Bootstrap critical values					Bootstrap critical values			
m	*t*-stat	10%	5%	1%	*p*-values	*t*-stat	10%	5%	1%	*p*-values
1	0.07	2.44	2.82	3.59	0.798	1.77	2.45	2.83	3.56	0.264
2	0.06	2.45	2.86	3.60	0.797	1.72	2.46	2.84	3.57	0.278
3	0.71	2.48	2.86	3.57	0.618	1.14	2.46	2.83	3.58	0.476
4	0.31	2.50	2.89	3.55	0.734	1.27	2.42	2.81	3.58	0.429
5	0.79	2.48	2.87	3.60	0.589	1.47	2.45	2.81	3.53	0.356
6	0.35	2.48	2.89	3.66	0.729	1.27	2.48	2.86	3.55	0.429
7	1.13	2.49	2.90	3.66	0.485	0.67	2.45	2.79	3.53	0.630
8	1.95	2.52	2.91	3.61	0.219	0.35	2.47	2.84	3.51	0.726
9	2.64	2.51	2.94	3.68	0.082	0.28	2.45	2.84	3.56	0.755
10	2.54	2.55	2.99	3.72	0.099	0.39	2.45	2.83	3.56	0.710
11	1.99	2.57	2.96	3.68	0.211	0.45	2.45	2.83	3.57	0.705
12	1.94	2.55	2.96	3.72	0.232	0.34	2.46	2.81	3.55	0.729

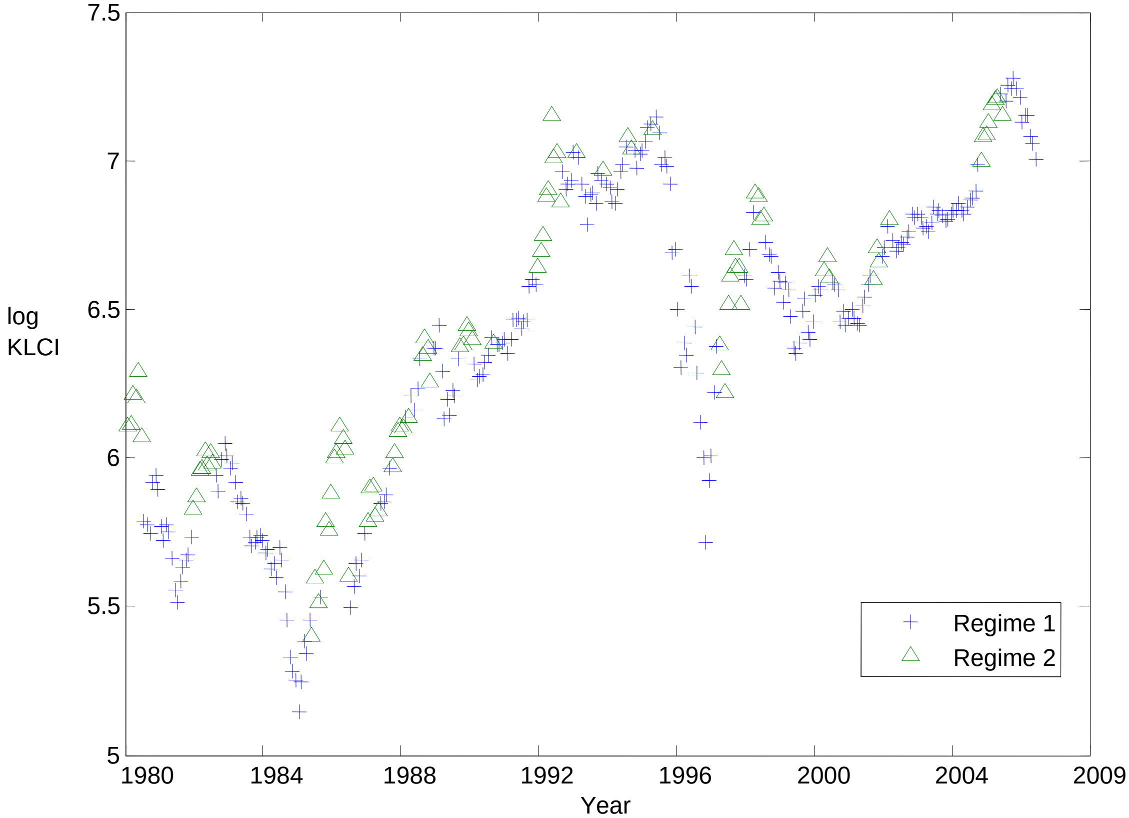
For our preferred specification of m = 5, we report LS estimates of TAR model in Table 4. The point estimate of the threshold $\hat{\lambda}$ is 0.138. This value implies that the TAR splits the regression into two regimes depending on whether the threshold variable $Z_{t-1} = y_{t-1} - y_{t-6}$ lies above or below 0.138. The first regime occurs when $Z_t < 0.138$, which happens when the KLCI has fallen, remained constant, or has risen by less than 13.8% over a 5-month period. First regime contains approximately 73% of the observations. The second regime is when $Z_t \geq 0.138$, which occurs when the KLCI has risen by more than13.8% over a 5-month period. Approximately 27% of the observations belong to the second regime. Looking at the point estimates, it appears that the coefficients on Δy_{t-1}, Δy_{t-3}, and Δy_{t-9} in regime1, and Δy_{t-3}, Δy_{t-7}, Δy_{t-8}, Δy_{t-9}, and Δy_{t-12} in regime 2, are deriving the threshold model, with other coefficient either less important invariant across regimes. Fig. 1 shows the estimated division of our data into two threshold regimes.

Table 4. Least Squares Estimates for the TAR Model

Regressors	$Z_{t-1} < \hat{\lambda} = 0.138$		$Z_{t-1} \geq \hat{\lambda} = 0.138$	
	Estimate	S.E	Estimate	S.E
y_{t-1}	-0.008	0.011	-0.026	0.018
Intercept	0.052	0.070	0.220	0.117
Δy_{t-1}	0.164*	0.067	-0.175	0.130
Δy_{t-2}	0.057	0.066	0.141	0.135
Δy_{t-3}	-0.134*	0.067	-0.449*	0.133
Δy_{t-4}	-0.073	0.068	-0.057	0.140
Δy_{t-5}	0.059	0.072	-0.148	0.123
Δy_{t-6}	-0.113	0.067	-0.094	0.099
Δy_{t-7}	0.065	0.070	0.190*	0.087
Δy_{t-8}	0.039	0.071	-0.226*	0.089
Δy_{t-9}	0.152*	0.072	-0.183*	0.088
Δy_{t-10}	0.104	0.069	0.158	0.088
Δy_{t-11}	-0.004	0.069	-0.100	0.086
Δy_{t-12}	0.072	0.066	-0.311*	0.092

* Indicates significance at 5% level or higher. Regime 1 and 2 contain 241 and 90 observations, respectively.

Fig. 1 : Kuala Lumpur Composite Index (KLCI), Classified by threshold Regime



4. Conclusions

In this paper we have investigated whether the Malaysia's Kuala Lumpur stock market is efficient or not using monthly stock price (KLCI) data for the 1980:1 to 2008:8 period. In order to achieve this, we have used two-regime threshold autoregressive (TAR) model suggested by Caner and Hansen (2001). Our findings indicate that the Kuala Lumpur stock market exhibits nonlinear behaviours with unit root. While the former finding is consistent with the evidence reported by Shively (2003) and Narayan (2005, 2006), and justifies our use of a TAR model, the latter finding is consistent with the efficient market hypothesis. This implies that returns on the Kuala Lumpur stock market cannot be predicted using its own history of stock prices.

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