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Structural breaks and testing for the random walk hypothesis in international stock prices

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Abstract

This paper examines whether stock prices for 16 countries are trend stationary or follow a random walk process using the (Zivot and Andrews, 1992) and (Lumsdaine and Papell, 1997) tests and monthly data (1987:12-2005:12). With one structural break, the ZA test results provide evidence in favour of random walk hypothesis in 14 countries. However, when two endogenously-determined structural breaks are considered, this hypothesis was rejected for only five countries, suggesting a robust conclusion regarding the non-stationarity of stock prices world wide. In addition, the dates of structural break in most cases point to the Asian crisis in the period 1996-1998.

Keywords

stock market, random walk, structural break

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Structural Breaks and Testing for the Random Walk Hypothesis in International Stock Prices*

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This paper examines whether stock prices for 16 countries are trend stationary or follow a random walk process using the (Zivot and Andrews, 1992) and (Lumsdaine and Papell, 1997) tests and monthly data (1987:12-2007:04). With one and two structural breaks, the ZA and LP test results provide evidence in favour of random walk hypothesis in 12 and 11 countries, respectively. Thus based on our empirical results the stock market price indices in majority of the countries exhibit a random walk. In addition, the dates of structural break in most cases point to the Asian crisis in the period 1996-1998.

JEL Classification: G14, G15, C22
Keywords: stock market, random walk, structural break

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1. INTRODUCTION

Vibrant stock markets are important to promote economic growth. The essential function of stock markets is to allocate funds from savers to investors, leading to more efficient allocation of resources and economic prosperity. However, stock markets can trouble the economy as a whole too. Previous studies in financial literature found that an inefficient market cannot serve the economy as much as an efficient market (Ma, 2004). Therefore, the efficient market hypothesis has been widely investigated in numerous financial studies. There are several approaches to testing the efficiency of stock markets. However, the random walk hypothesis has been broadly used by a large number of financial analysts.

The issue of whether stock prices can be characterized as random walk[1)] or trend stationary process has been widely investigated. If stock prices follow a random walk process, any shocks to stock prices will be permanent and future returns cannot be forecasted by using information on historical prices. Nevertheless, if stock prices follow a trend stationary process, the price level returns will revert to its trend path over time and future returns can be predicted by using historical prices (Chaudhuri and Wu, 2003). The term random walk describes the movements of stock prices cannot be predicted because they can change without frontier in the long run. Although the subject of random walk in stock prices has been studied before, there is no consensus among analysts due to the inconclusive results in the literature.

Fama (1970) and Fama and French (1988) first found that the U.S. stock prices are trend stationary. In addition, using variance ratio tests, Lo and MacKinlay (1988) and Poterba and Summers (1988) also offered some evidences of trend stationary in the US stock prices. On the other hand, more recently Kim, Nelson, and Startz (1991) and McQueen (1992) demonstrated that the results of trend stationary in U.S. stock prices are not robust to

[1)] Gujarati (2003) argues that the terms random walk, unit root and nonstationarity can be used interchangeably. However, while every random walk is an $I(1)$ process, the reverse is not always the case.

outliers or alternative distributional assumptions. A number of studies have also investigated the trend stationary property for international stock prices. However, evidence of random walk or trend stationary process in stock prices is quite mixed (Urrutia, 1995; Zhen, 1998; Malliaropulos and Priestley, 1999; Balvers *et al.*, 2000).

The issue of structural breaks in macroeconomic time series has been subject to an extensive investigation. Structural breaks manifest themselves in the time series data for a number of reasons for instance economic crises, policy changes and regime shifts. Perron (1989) argued that if structural breaks are not dealt with appropriately, one may obtain spurious results. However, there are few studies which have incorporated structural breaks in testing for unit roots in stock prices. Chaudhuri and Wu (2003) employed one structural break proposed by Zivot and Andrews (1992), hereafter ZA, to test the random walk hypothesis in stock prices of 17 emerging markets. They found evidence of trend stationary for ten out of eighteen stock markets. Narayan and Smyth (2005) investigated the existence of random walk for OECD countries using the ZA test. Similar to the present study, their findings also provided strong support for the random walk hypothesis.

The major objective of this paper is to investigate the random walk hypothesis in stock prices of 16 countries for which we could obtain consistent and comparable time series data. We first begin with the conventional unit root tests which do not consider any structural breaks in the data, i.e., the Augmented Dickey-Fuller (ADF) test and the Dickey-Fuller Generalize Lease Square (DF-GLS) test. We then employ more relevant unit root tests which allow one structural break, ZA test, and two structural breaks (Lumsdaine and Papell, 1997, hereafter LP) to examine the significance of structural breaks. These two tests will empirically determine the most significant structural break in the data.

The remainder of the paper is structured as follows. Section 2 discusses briefly the empirical methodology utilized in the analysis. Then section 3 describes the summary statistics of the data employed. Section 4 presents the empirical econometric results as well as policy implications of the study. The paper ends with some concluding remarks.

2. METHODOLOGY

We perform the ADF unit root test to examine the time series properties of the data without allowing for any structural breaks. The ADF test (Dickey and Fuller, 1979) is conducted using the following equation

$$\Delta y_t = \mu + \beta t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t, \tag{1}$$

where y_t denotes the time series being tested, Δ is the first different operator, t is a time trend term, k denotes the number of lagged terms and ε is a white noise disturbance term. In this paper, the lowest value of the Schwartz Information Criterion (SIC) has been used as a guide to determine the optimal lag in the ADF regression. These lags augment the ADF regression to ensure that the error is white noise and free of serial correlation. To select the lag length, we use the sequential procedure suggested by Campbell and Perron (1991) with the maximum lag length (k_{max}) set to 12. In addition, the DF-GLS test proposed by Elliott *et al.* (1996) has been used as an alternative nonparametric model of controlling for serial correlation when testing for a unit root.

An important shortcoming associated with the ADF test and the DF-GLS test is that they do not allow for the effect of structural breaks. Perron (1989) argued that if a structural break in a series is ignored, unit root tests can be erroneous in rejecting null hypothesis. Perron (1989) proposed models which allow for one-time structural break in equation (1). Moreover, ZA (1992) have developed methods to endogenously search for a structural break in the data. We employed model C which allows for a structural break in both the intercept and slope in the following equation

$$\Delta y_t = \mu + \beta t + \theta DU_t + \gamma DT_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t, \quad (2)$$

where $DU_t = 1$ if $t > TB$, otherwise zero; TB denotes the time of break, $DT_t = t - TB$ if $t > TB$, otherwise zero. The lag length is selected using the same approach as in the ADF test. The "trimming region" in which we have searched for TB cover the 0.15T-0.85T period. We have chosen the break point base on the minimum value of t statistic for α.

As Ben-David, Lumsdaine and Papell (2003) argued, if there are two structural breaks in the deterministic trend, then unit root tests with one structural break will also lead to a misleading conclusion. LP (1997) argued that unit root test that account for two structural breaks is more powerful than those, which only accommodate for one structural break. They introduced a new procedure to capture two structural breaks as an extension of model C by including two endogenous breaks in equation (1). Consequently, model CC can be represented as follows

$$\Delta y_t = \mu + \beta t + \theta DU1_t + \gamma DT1_t + \omega DU2_t + \psi DT2_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t, (3)$$

where $DU1_t = 1$ if $t > TB1$, otherwise zero; $DU2_t = 1$ if $t > TB2$, otherwise zero; $DT1_t = t - TB1$ if $t > TB1$, otherwise zero; $DT2_t = t - TB2$ if $t > TB2$, otherwise zero. Two dummy variables (i.e., $DU1_t$ and $DU2_t$) are indicators for structural breaks in the intercept at $TB1$ and $TB2$, respectively. However, the other dummy variables (i.e., $DT1_t$ and $DT2_t$) are indicators for structural breaks in trend at $TB1$ and $TB2$, respectively. The lag length and break points are selected using the same approach as in the ZA test.

3. THE DATA

Sample data included in this paper are stock prices from the following 16 countries: Argentina (AR), Australia (AU), Brazil (BA), Germany (GE),

Table 1 Descriptions of the Data Employed

Variable	Mean	Median	Maximum	Minimum	Standard deviation	Skewness	Kurtosis	Jarque-Bera	p-value
$\Delta \ln P_t^{AR} = \Delta \ln P_t^1$	0.015	0.014	0.670	–0.486	0.149	0.571	6.694	144.498	0.000
$\Delta \ln P_t^{AU} = \Delta \ln P_t^2$	0.007	0.007	0.157	–0.166	0.052	–0.265	3.478	4.927	0.085
$\Delta \ln P_t^{BA} = \Delta \ln P_t^3$	0.014	0.025	0.595	–1.107	0.164	–1.419	12.859	1017.497	0.000
$\Delta \ln P_t^{GE} = \Delta \ln P_t^4$	0.008	0.012	0.202	–0.279	0.063	–0.742	5.669	90.142	0.000
$\Delta \ln P_t^{HK} = \Delta \ln P_t^5$	0.008	0.009	0.284	–0.344	0.075	–0.222	5.563	65.420	0.000
$\Delta \ln P_t^{IN} = \Delta \ln P_t^6$	0.007	0.011	0.662	–0.525	0.141	0.373	7.539	204.508	0.000
$\Delta \ln P_t^{JA} = \Delta \ln P_t^7$	0.000	–0.002	0.217	–0.216	0.065	0.068	3.591	3.562	0.168
$\Delta \ln P_t^{KO} = \Delta \ln P_t^8$	0.006	–0.001	0.534	–0.375	0.108	0.301	6.213	103.268	0.000
$\Delta \ln P_t^{MA} = \Delta \ln P_t^9$	0.006	0.009	0.405	–0.361	0.088	–0.253	7.000	157.156	0.000
$\Delta \ln P_t^{PH} = \Delta \ln P_t^{10}$	0.005	0.006	0.360	–0.347	0.094	–0.064	4.810	31.832	0.000
$\Delta \ln P_t^{RU} = \Delta \ln P_t^{11}$	0.017	0.029	0.477	–0.931	0.179	–1.096	8.102	190.152	0.000
$\Delta \ln P_t^{SG} = \Delta \ln P_t^{12}$	0.007	0.011	0.228	–0.231	0.069	–0.560	5.513	73.188	0.000
$\Delta \ln P_t^{TA} = \Delta \ln P_t^{13}$	0.004	0.002	0.381	–0.410	0.109	–0.037	4.392	18.777	0.000
$\Delta \ln P_t^{TH} = \Delta \ln P_t^{14}$	0.003	0.007	0.359	–0.416	0.116	–0.405	4.974	44.025	0.000
$\Delta \ln P_t^{UK} = \Delta \ln P_t^{15}$	0.006	0.005	0.138	–0.111	0.044	0.015	3.227	0.505	0.777
$\Delta \ln P_t^{US} = \Delta \ln P_t^{16}$	0.008	0.011	0.106	–0.151	0.040	–0.580	4.079	24.275	0.000

Note: Data employed covering the period December 1987 to April 2007 except for the stock price index of Russia December 1994 to April 2007.
Source: Morgan Stanley Capital International, http://www.msci.com/equity/index2.html.

Hong Kong (HK), Indonesia (IN), Japan (JA), Korea (KO), Malaysia (MA), the Philippines (PH), Russia (RU), Singapore (SG), Taiwan (TA), Thailand (TH), the UK and the US. Seven of these markets are categorized as developed market (e.g., Australia, Germany, Hong Kong, Japan, Singapore, the UK and the US) and the remainder is regarded as emerging market. Monthly data span from December 1987 to April 2007 with a base value of 100 in December 1987, except for the stock price index of Russia which covers the period December 1994 to April 2007 with a base value of 100 in December 1994. This different base year has been modified accordingly. All stock indices were obtained from Morgan Stanley Capital International.

Table 1 presents the descriptive statistics of the data. Sample means, medians, maximums, minimums, standard deviations, skewness, kurtosis as well as the Jarque-Bera statistics and *p*-values are presented. The highest mean return is 0.017% in Russia and the lowest is 0.000% in Japan. The standard deviations range from 0.040% (the least volatile) to 0.178% (the most volatile). The standard deviations of stock returns are lowest in developed economies (i.e., the US, the UK, Australia, Germany and Japan), and the most volatile in Russia, Brazil, Argentina, Indonesia, Thailand and Taiwan. All monthly stock returns, $\ln(P_t/P_{t-1})$, have excess kurtosis which means that they have a thicker tail and a higher peak than a normal distribution. The calculated Jarque-Bera statistics and corresponding *p*-values are used to test for the normality assumption. Base on the Jarque-Bera statistics and *p*-values, this assumption is rejected at any conventional level of significance for all stock returns, with the only two exceptions being the monthly stock returns in Japan and the UK.

4. EMPIRICAL RESULTS AND POLICY IMPLICATIONS

As mentioned earlier, we first used the ADF test and the DF-GLS test to determine the order of integration of the 16 stock prices studied in this paper. Based on the results of both the ADF test and the DF-GLS test presented in

Table 2 Unit Root Test Results

Variable	ADF Test Constant and Trend		DF-GLS Test Constant and Trend	
$\ln P_t^{AR} = \ln P_t^1$	–2.483	(0)	–1.308	(0)
$\Delta \ln P_t^{AR} = \Delta \ln P_t^1$	–14.846***	(0)	–14.664***	(0)
$\ln P_t^{AU} = \ln P_t^2$	–1.397	(0)	–1.711	(0)
$\Delta \ln P_t^{AU} = \Delta \ln P_t^2$	–16.481***	(0)	–12.814***	(0)
$\ln P_t^{BA} = \ln P_t^3$	–2.998	(0)	–2.477	(0)
$\Delta \ln P_t^{BA} = \Delta \ln P_t^3$	–17.584***	(0)	–8.289***	(1)
$\ln P_t^{GE} = \ln P_t^4$	–1.990	(0)	–1.845	(0)
$\Delta \ln P_t^{GE} = \Delta \ln P_t^4$	–16.055***	(0)	–2.334	(5)
$\ln P_t^{HK} = \ln P_t^5$	–2.129	(0)	–1.517	(0)
$\Delta \ln P_t^{HK} = \Delta \ln P_t^5$	–14.387***	(0)	–14.386***	(0)
$\ln P_t^{IN} = \ln P_t^6$	–2.164	(1)	–1.350	(1)
$\Delta \ln P_t^{IN} = \Delta \ln P_t^6$	–12.788***	(0)	–12.803***	(0)
$\ln P_t^{JA} = \ln P_t^7$	–1.975	(0)	–2.066	(0)
$\Delta \ln P_t^{JA} = \Delta \ln P_t^7$	–14.660***	(0)	–13.132***	(0)
$\ln P_t^{KO} = \ln P_t^8$	–1.540	(0)	–1.683	(0)
$\Delta \ln P_t^{KO} = \Delta \ln P_t^8$	–14.650***	(0)	–2.596	(5)
$\ln P_t^{MA} = \ln P_t^9$	–2.628	(2)	–2.046	(2)
$\Delta \ln P_t^{MA} = \Delta \ln P_t^9$	–7.749***	(1)	–7.439***	(1)
$\ln P_t^{PH} = \ln P_t^{10}$	–1.960	(1)	–1.217	(1)
$\Delta \ln P_t^{PH} = \Delta \ln P_t^{10}$	–12.181***	(0)	–12.215***	(0)
$\ln P_t^{RU} = \ln P_t^{11}$	–2.309	(0)	–2.263	(0)
$\Delta \ln P_t^{RU} = \Delta \ln P_t^{11}$	–10.619***	(0)	–3.472**	(3)
$\ln P_t^{SG} = \ln P_t^{12}$	–2.082	(0)	–1.405	(0)
$\Delta \ln P_t^{SG} = \Delta \ln P_t^{12}$	–14.761***	(0)	–8.162***	(1)
$\ln P_t^{TA} = \ln P_t^{13}$	–3.807**	(0)	–1.761	(0)
$\Delta \ln P_t^{TA} = \Delta \ln P_t^{13}$	–13.645***	(0)	–5.258**	(2)
$\ln P_t^{TH} = \ln P_t^{14}$	–1.874	(0)	–1.170	(0)
$\Delta \ln P_t^{TH} = \Delta \ln P_t^{14}$	–9.0132***	(1)	–2.927**	(6)
$\ln P_t^{UK} = \ln P_t^{15}$	–1.891	(0)	–1.877	(0)
$\Delta \ln P_t^{UK} = \Delta \ln P_t^{15}$	–12.745***	(1)	–15.228***	(0)
$\ln P_t^{US} = \ln P_t^{16}$	–1.331	(0)	–1.147	(0)
$\Delta \ln P_t^{US} = \Delta \ln P_t^{16}$	–15.844***	(0)	–14.590***	(0)

Notes: a) Data employed covering the period December 1987 to April 2007 except for the stock price index of Russia December 1994 to April 2007. b) Figures in parentheses are lag lengths for the ADF test and the DF-GLS test. c) *, ** and *** indicates that the corresponding null hypothesis is rejected at the 10, 5 and 1% significance level, respectively.

table 2, the null hypothesis (unit root) cannot be rejected for all 16 countries, with the only exception being the case of Taiwan. While the ADF test indicates that the stock market in Taiwan is *I*(0), the DF-GLS test still supports the random walk hypothesis. Therefore, we concluded that all stock prices employed in this paper are *I*(1), in other words, they follow a random walk.

In the second stage, we subject each variable to one and two structural breaks. For each series, we then estimated model C and reported the results in table 3. As mentioned earlier, the ADF and DF-GLS test results reveal that all stock prices examined in this paper followed a random walk, whereas the results of the ZA test show that the stock prices for four countries (i.e., Indonesia, Korea, Malaysia and Russia) are now stationary. These same four countries also follow an *I*(0) process according to the LP test as discussed below. The remaining 12 countries still contain a unit root in the data. The estimated coefficients μ and θ are statistically significant for all variables except for μ in case of Russian stock prices. Thus at least there has been one structural break in the intercept during the sample period for all stock prices. The estimated coefficients for β and γ are statistically significant in 12 and 11 out of 16 countries, respectively, implying the stock price series exhibit an upward or downward trend and there exist at least one structural break in trend in these ten countries.

The reported *TB*s are endogenously determined in the ZA test and presented in the second column of table 3. It is not surprising to note that the most important structural breaks in these stock prices occurred in the Asian crisis period 1996-1998, see *TB*s for Indonesia, Korea, Malaysia, the Philippines, Russia, Singapore, Thailand, and the US.

Table 4 presents the results of the LP test allowing for the two most significant structural breaks. The results show that the stock prices for five countries (i.e., Argentina, Indonesia, Korea, Malaysia and Russia) become stationary now. Comparing the results of the ZA and LP tests, as can be seen from tables 3 and 4, shows that the addition of another endogenous break in the data can marginally change the order of integration of the variables: only

Table 3 The Zivot and Andrews Test Results: Break in Both Intercept and Trend:

$$\Delta y_t = \mu + \beta t + \theta DU_t + \gamma DT_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t$$

Variable	TB	μ	β	θ	γ	α	k	Inference
$\ln P_t^{AR} = \ln P_t^{1}$	2001:02	0.449 (3.856)***	0.001 (1.740)*	–0.163 (–3.019)***	0.002 (2.911)***	–0.072 (–3.521)	0	Random walk
$\ln P_t^{AU} = \ln P_t^{2}$	2001:02	0.746 (3.990)***	0.001 (3.143)***	–0.120 (–1.861)*	-0.061 (-3.06)***	–0.155 (–3.947)	4	Random walk
$\ln P_t^{BA} = \ln P_t^{3}$	2001:02	0.628 (3.380)***	0.002 (2.587)**	–0.164 (–2.805)***	0.002 (2.129)**	–0.123 (–3.293)	12	Random walk
$\ln P_t^{GE} = \ln P_t^{4}$	2002:04	0.533 (3.417)***	0.001 (2.684)***	–0.102 (–3.357)***	0.002 (3.394)***	–0.111 (–3.292)	9	Random walk
$\ln P_t^{HK} = \ln P_t^{5}$	1993:01	0.537 (3.661)***	0.002 (2.132)**	0.053 (1.785)*	–0.001 (–1.999)**	–0.119 (–3.696)	11	Random walk
$\ln P_t^{IN} = \ln P_t^{6}$	1997:08	0.721 (5.608)***	0.000 (0.461)	–0.249 (–4.792)***	0.001 (2.416)	–0.118 (–5.535)**	8	Stationary
$\ln P_t^{JA} = \ln P_t^{7}$	2002:06	0.633 (4.283)***	–0.000 (–2.334)**	–0.060 (–2.480)**	0.002 (3.305)***	–0.134 (–4.304)	9	Random walk
$\ln P_t^{KO} = \ln P_t^{8}$	1997:09	0.952 (5.559)***	–0.000 (–0.554)	–0.159 (–4.007)***	0.003 (4.594)***	–0.189 (–5.581)***	9	Stationary
$\ln P_t^{MA} = \ln P_t^{9}$	1997:07	0.858 (6.428)***	0.002 (4.842)***	–0.235 (–6.121)***	–0.001 (–2.099)**	–0.179 (–6.361)***	11	Stationary
$\ln P_t^{PH} = \ln P_t^{10}$	1999:05	0.264 (2.735)***	0.000 (0.974)	–0.095 (–2.775)***	0.000 (0.495)	–0.049 (–2.518)	12	Random walk
$\ln P_t^{RU} = \ln P_t^{11}$	1998:05	–0.477 (–1.517)	0.021 (4.805)***	–0.598 (–5.692)***	–0.013 (–3.576)***	–0.344 (–6.458)***	7	Stationary
$\ln P_t^{SG} = \ln P_t^{12}$	1997:03	0.385 (3.005)***	0.001 (2.166)**	–0.066 (–2.814)***	–0.000 (–0.827)	–0.079 (–2.923)	7	Random walk
$\ln P_t^{TA} = \ln P_t^{13}$	1993:10	0.821 (3.941)***	–0.002 (–1.961)*	0.095 (2.658)***	0.001 (1.643)	–0.140 (–4.028)	9	Random walk
$\ln P_t^{TH} = \ln P_t^{14}$	1996:10	0.411 (4.123)***	0.001 (1.349)	–0.172 (–3.789)***	0.000 (0.128)	–0.076 (–3.923)	12	Random walk
$\ln P_t^{UK} = \ln P_t^{15}$	2001:01	0.373 (3.218)***	0.001 (2.884)***	–0.063 (–3.822)***	0.001 (2.215)**	–0.081 (–3.140)	2	Random walk
$\ln P_t^{US} = \ln P_t^{16}$	1996:09	0.293 (3.292)***	0.001 (2.466)**	0.033 (2.335)**	–0.000 (–2.342)**	–0.062 (–3.223)	7	Random walk

Notes: a) Data employed covering the period December 1987 to April 2007 except for the stock price index of Russia December 1994 to April 2007. b) *, ** and *** indicates that the corresponding null hypothesis is rejected at the 10, 5 and 1% significance level, respectively. c) Critical values for t_α at the 10, 5, and 1% are –4.82, –5.08 and –5.57, respectively (Zivot and Andrews, 1992).

Table 4 The Lumsdaine and Papell Test Results: Break in Both Intercept and Trend:

$$\Delta y_t = \mu + \beta t + \theta DU1_t + \gamma DT1_t + \omega DU2_t + \psi DT2_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t$$

Variable	$TB1$	$TB2$	μ	β	θ	γ	ω	ψ	α	k	Inference
$\ln P_t^{AR} = \ln P_t^1$	1991:08	2002:01	1.722 (7.883)***	0.010 (4.231)***	0.758 (6.364)***	–0.010 (–4.193)***	–2.580 (–7.427)***	0.012 (7.407)***	–0.348 (–7.755)***	4	Stationary
$\ln P_t^{AU} = \ln P_t^2$	1993:07	2002:06	1.187 (6.390)***	0.000 (0.012)	0.052 (2.185)**	0.000 (0.865)	–0.843 (–5.931)***	0.005 (6.117)***	–0.244 (–6.317)	0	Random walk
$\ln P_t^{BA} = \ln P_t^3$	1998:08	2002:06	1.482 (5.348)***	0.005 (4.943)***	0.512 (1.757)*	–0.005 (–2.523)**	–2.008 (–3.967)***	0.010 (3.695)***	–0.315 (–5.319)	12	Random walk
$\ln P_t^{GE} = \ln P_t^4$	1998:02	2002:05	0.980 (5.155)***	0.002 (4.435)***	0.446 (4.346)***	–0.003 (–4.182)***	–1.039 (–5.806)***	0.005 (5.580)***	–0.207 (–5.088)	9	Random walk
$\ln P_t^{HK} = \ln P_t^5$	1997:10	2002:05	1.160 (6.051)***	0.004 (5.680)***	0.248 (2.287)**	–0.003 (–3.536)***	–0.536 (–3.273)***	0.002 (2.685)***	–0.258 (–5.983)	10	Random walk
$\ln P_t^{IN} = \ln P_t^6$	1997:08	2003:02	1.189 (6.913)***	0.001 (1.509)	0.041 (0.280)	–0.003 (–2.227)**	–1.189 (–3.224)***	0.007 (3.510)***	–0.199 (–6.831)**	8	Stationary
$\ln P_t^{JA} = \ln P_t^7$	1993:05	2002:06	1.006 (5.497)***	–0.002 (–3.492)***	–0.019 (–0.564)	0.002 (2.564)**	–0.694 (–4.661)***	0.004 (4.728)***	–0.200 (–5.553)	9	Random walk
$\ln P_t^{KO} = \ln P_t^8$	1993:11	1997:10	1.598 (6.759)***	–0.003 (–3.145)***	0.107 (0.957)	0.001 (0.545)	–0.963 (–5.815)***	0.006 (4.663)***	–0.302 (–6.899)**	11	Stationary
$\ln P_t^{MA} = \ln P_t^9$	1993:08	1997:08	1.120 (7.125)***	0.002 (2.583)**	0.149 (1.875)*	–0.001 (–0.939)	–0.329 (–3.658)***	0.001 (0.708)	–0.229 (–7.158)**	12	Stationary

Variable	$TB1$	$TB2$	μ	β	θ	γ	ω	ψ	α	k	Inference
$\ln P_t^{PH} = \ln P_t^{10}$	1995:11	2002:10	1.031 (5.331)***	0.004 (4.533)***	0.921 (4.890)***	–0.009 (–5.013)***	–1.720 (–5.021)***	0.009 (5.148)***	–0.224 (–5.245)	12	Random walk
$\ln P_t^{RU} = \ln P_t^{11}$	1997:11	1998:05	1.275 (6.387)***	0.031 (5.660)***	0.005 (0.004)	–0.006 (–0.173)	0.058 (0.042)	–0.015 (–0.420)	–0.383 (–7.103)**	7	Stationary
$\ln P_t^{SG} = \ln P_t^{12}$	1997:06	2002:06	1.131 (5.466)***	0.002 (4.543)***	0.137 (1.621)	–0.002 (–2.949)***	–0.733 (–4.225)***	0.003 (3.923)***	–0.236 (–5.378)	12	Random walk
$\ln P_t^{TA} = \ln P_t^{13}$	1990:03	2000:09	1.064 (5.279)***	0.014 (2.791)***	0.071 (0.702)	–0.013 (–2.564)**	–0.162 (–1.697)*	–0.000 (–0.005)	–0.226 (–6.203)	9	Random walk
$\ln P_t^{TH} = \ln P_t^{14}$	1993:10	2000:05	0.807 (5.309)***	0.001 (1.346)	0.542 (4.302)***	–0.006 (–3.867)***	–1.121 (–4.938)***	0.007 (4.969)***	–0.154 (–5.295)	12	Random walk
$\ln P_t^{UK} = \ln P_t^{15}$	1997:05	2002:06	0.828 (4.838)***	0.001 (4.531)***	0.319 (5.043)***	–0.002 (–4.991)***	–0.694 (–5.504)***	0.004 (5.617)***	–0.180 (–4.816)	2	Random walk
$\ln P_t^{US} = \ln P_t^{16}$	1998:09	2002:04	0.518 (4.596)***	0.001 (4.417)***	0.418 (4.873)***	–0.003 (–4.893)***	–0.514 (–5.076)***	0.002 (4.887)***	–0.112 (–4.529)	0	Random walk

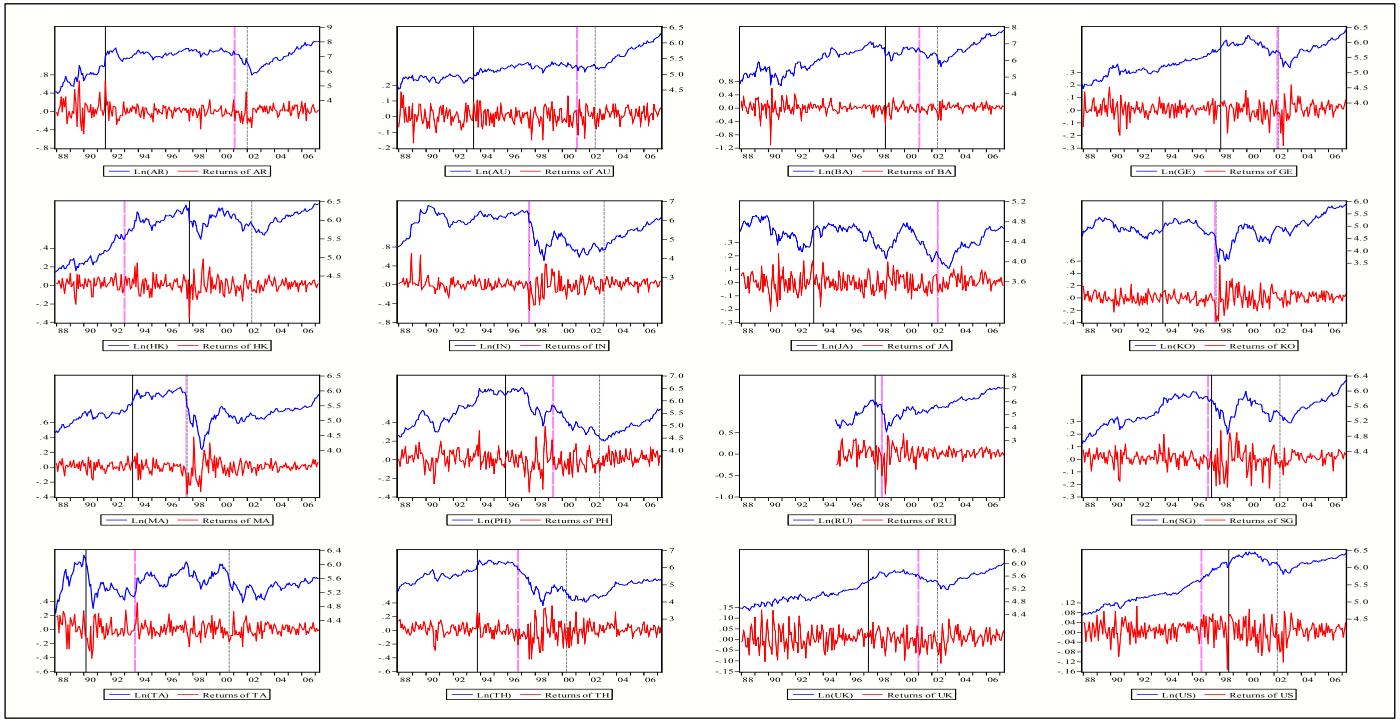
Notes: a) Data employed covering the period December 1987 to April 2007 except for the stock price index of Russia December 1994 to April 2007. b) *, ** and *** indicates that the corresponding null hypothesis is rejected at the 10, 5 and 1% significance level, respectively. c) Critical values for t_α at the 10, 5, and 1% are –6.49, –6.82 and –7.34, respectively (Lumsdaine and Papell, 1997).

one more country (Argentina) now exhibits a stationary process. So our conclusion regarding the order of integration of the stock market price indices remain robust. It should be noted that the estimated coefficients for θ, γ, ω and ψ are significant for the stock prices of Argentina, Brazil, Germany, Hong Kong, the Philippines, the UK and the US, indicating that the reported structural changes at *TB*1 and *TB*2 (table 4) have impacted on both the intercept and trend. In the case of Indonesia, Japan and Singapore, while γ, ω, and ψ are significant, θ is not, suggesting that the second structural break occurred at *TB*2 has affected both the intercept and slope but the first one exerted a significant change in trend only. Finally based on the magnitudes of *t*-ratios for θ, γ, ω, and ψ, while the second structural break in Korea shifted both the intercept and slope, the first one had no significant effect.

Figure 1 shows the log and the monthly return of each of the 16 stock prices employed as well as their corresponding structural breaks – the thick dashed line denotes *TB* for the ZA test and the solid and thin dashed lines are used to show *TB*1 and *TB*2 in the LP test, respectively. The *TB*1s and *TB*2s are presented in the second and third column of table 4. The results are quite consistent in identifying structural breaks in most stock prices. *TB* in the ZA test is the same as that of either *TB*1 or *TB*2 in the LP test for the following seven countries: Germany, Indonesia, Japan, Korea, Malaysia, Russia and Singapore.

In order to facilitate the cross model comparison, the times of structural breaks obtained by the ZA test and the LP test are presented in table 5. As mentioned earlier, the results from both tests are quite consistent. The most significant break occurred during various months in the period 1996-1998 for seven and ten countries in the ZA test and the LP test, respectively. Two other important breaks across various markets occurred in 1991-1993 and 2000-2002, which coincided with two world-wide recessions. Based on the ZA test, in two countries the structural break occurred in 1991-1993 and six countries it happened in 2000-2002. On the other hand, the LP test results in table 5 show that in five countries the first break occurred in 1991-1993, and for 12 countries the second break was identified in 2000-2002. Apart from

Figure 1 Plot of Stock Price Indices



Source: Morgan Stanley Capital International, http://www.msci.com/equity/index2.html.

Table 5 Comparing the Time of Structural Breaks for the Zivot and Andrews Test and Lumsdaine and Papell Test Results

Variable	Zivot and Andrews Test		Lumsdaine and Papell Test			
	TB	Possible causes for *TB*s	*TB*1	Possible causes for *TB*1s	*TB*2	Possible causes for *TB*2s
$\ln P_t^{AR} = \ln P_t^1$	2001:02	Global recession 2000-2002	1991:08	Global recession 1991-1993	2002:01	Global recession 2000-2002
$\ln P_t^{AU} = \ln P_t^2$	2001:02	Global recession 2000-2002	1993:07	Global recession 1991-1993	2002:06	Global recession 2000-2002
$\ln P_t^{BA} = \ln P_t^3$	2001:02	Global recession 2000-2002	1998:08	Asian crisis	2002:06	Global recession 2000-2002
$\ln P_t^{GE} = \ln P_t^4$	2002:04	Global recession 2000-2002	1998:02	Asian crisis	2002:05	Global recession 2000-2002
$\ln P_t^{HK} = \ln P_t^5$	1993:01	Global recession 1991-1993	1997:10	Asian crisis	2002:05	Global recession 2000-2002
$\ln P_t^{IN} = \ln P_t^6$	1997:08	Asian crisis	1997:08	Asian crisis	2003:02	Domestic event
$\ln P_t^{JA} = \ln P_t^7$	2002:06	Global recession 2000-2002	1993:05	Global recession 1991-1993	2002:06	Global recession 2000-2002
$\ln P_t^{KO} = \ln P_t^8$	1997:09	Asian crisis	1993:11	Global recession 1991-1993	1997:10	Asian crisis
$\ln P_t^{MA} = \ln P_t^9$	1997:07	Asian crisis	1993:08	Global recession 1991-1993	1997:08	Asian crisis
$\ln P_t^{PH} = \ln P_t^{10}$	1999:05	Asian crisis	1995:11	Domestic event	2002:10	Global recession 2000-2002
$\ln P_t^{RU} = \ln P_t^{11}$	1998:05	Asian crisis	1997:11	Asian crisis	1998:05	Asian crisis
$\ln P_t^{SG} = \ln P_t^{12}$	1997:03	Asian crisis	1997:06	Asian crisis	2002:06	Global recession 2000-2002
$\ln P_t^{TA} = \ln P_t^{13}$	1993:10	Global recession 1991-1993	1990:03	Domestic event	2000:09	Global recession 2000-2002
$\ln P_t^{TH} = \ln P_t^{14}$	1996:10	Asian crisis	1993:10	Global recession 1991-1993	2000:05	Global recession 2000-2002
$\ln P_t^{UK} = \ln P_t^{15}$	2001:01	Global recession 2000-2002	1997:05	Asian crisis	2002:06	Global recession 2000-2002
$\ln P_t^{US} = \ln P_t^{16}$	1996:09	Asian crisis	1998:09	Asian crisis	2002:04	Global recession 2000-2002

Note: Data employed covering the period December 1987 to April 2007 except for the stock price index of Russia December 1994 to April 2007.

the 1997-1998 Asian crisis and the above two global recessions, these have been several other country-specific events which caused jitters in financial markets (see table 5).

5. CONCLUDING REMARKS

The main purpose of this empirical analysis is to examine the random walk hypothesis in the stock prices of 16 countries for which there were consistent monthly data available. The results of the ADF test and the DF-GLS test suggest that there is a unit root in almost all stock prices; supporting a random walk hypothesis. However, after incorporating one structural break in the data, the ZA test found evidence in favour of random walk hypothesis for 12 countries. By applying the LP test, which allows for two endogenously determined structural breaks in each series, we obtained similar results, supporting the view that the random walk hypothesis is again applicable for majority of countries (11 out of 16). Thus allowing for more structural breaks in the data did not lead to a reversal of our inference regarding the order of the integration of the variables employed.

That is to say, while monthly stock prices in Argentina, Indonesia, Korea, Malaysia and Russia were $I(0)$, the stock prices in the rest of countries continued to follow a random walk process. According to the weak form of the efficient market hypothesis, stock prices completely reflect the information contained in the data and consequently no one can devise an investment strategy to obtain abnormal profits on the basis of an analysis of past price patterns. In this paper we found some empirical evidence that supports previous statement. In other words, majority of market prices evolve according to a random walk and as such they cannot be predicted using historical data despite considering up to two significant structural breaks in the data.

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