Weak-Form Market Efficiency in Asian Emerging and Developed Equity Markets: Comparative Tests of Random Walk Behaviour

A. C. Worthington*   H. Higgs†

*University of Wollongong, a.worthington@griffith.edu.au
†Griffith University, h.higgs@griffith.edu.au

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Weak-Form Market Efficiency in Asian Emerging and Developed Equity Markets: Comparative Tests of Random Walk Behaviour

Andrew Worthington
School of Accounting and Finance
University of Wollongong

and

Helen Higgs
School of Economics and Finance
Queensland University of Technology

Abstract

This paper examines the weak-form market efficiency of Asian equity markets. Daily returns for ten emerging (China, India, Indonesia, Korea, Malaysia, Pakistan, the Philippines, Sri Lanka, Taiwan and Thailand) and five developed markets (Australia, Hong Kong, Japan, New Zealand and Singapore) are examined for random walks using serial correlation coefficient and runs tests, Augmented Dickey-Fuller, Phillips-Perron and Kwiatkowski, Phillips, Schmidt and Shin unit root tests and multiple variance ratio tests. The serial correlation and runs tests conclude that all of the markets are weak-form inefficient. The unit root tests suggest weak-form efficiency in all markets, with the exception of Australia and Taiwan. The results from the more stringent variance ratio tests indicate that none of the emerging markets are characterised by random walks and hence are not weak-form efficient, while only the developed markets in Hong Kong, New Zealand and Japan are consistent with the most stringent random walk criteria.

1. Introduction

Study of the stock return generating process has long been dominated by interest in its random walk properties. Justification for such interest is not hard to find, given that the presence (or absence) of a random walk has important implications for investors and trading strategies, fund managers and asset pricing models, capital markets and market efficiency, and consequently financial and economic development as a whole. Trading strategies, for example, differ when returns are characterised by random walks or by positive autocorrelation (or persistence) over short horizons and negative autocorrelation (or mean reversion) over long horizons. In this instance, and as the investment horizon lengthens, an investor would invest more (less) in stocks if the relative risk aversion is greater (less) than unity, than if the returns were serially independent.

Similarly, random walks in stock returns are crucial to the formulation of rational expectations models and the testing of (weak-form) market efficiency. In an efficient market the prices of stocks fully incorporate all relevant information and hence stock returns will display unpredictable behaviour. In stock prices not characterised by a random walk, the return generating process is dominated by a temporary component and therefore future returns can be predicted by the historical sequence of returns. Lastly, the ability of stock markets to play the role that is ascribed to them – attracting foreign investment, boosting domestic saving and improving the pricing and availability of capital – depends upon the presence of random walks. A market following a random walk is consistent with equity being appropriately priced at an equilibrium level, whereas the absence of a random walk infers distortions in the pricing of capital and risk. This has important implications for the allocation of capital within an economy and hence overall economic development.

This paper examines the random walk behaviour of a large number of Asian emerging and developed markets. Past studies of random walks and market efficiency in Asian equity markets have tended to focus on a single, often developed, market [see, for example, Groenewold and Kang (1993), Ayadi and Pyun (1994), Lian and Leng (1994), Huang (1995), Groenewold and Ariff (1998), Los (2000), Lee et al. (2001) and Ryoo and Smith (2002)]. The current analysis also includes a number of alternative, though complementary, testing procedures. With few exceptions, previous research has relied upon a single, often inexact, testing procedure [see, for instance, Poshakwale (1996), Karemara et al. (1999), Ryoo and Smith (2002) and Abraham et al. (2002)]. Finally, this paper uses daily data to detect violations of the random walk hypothesis likely to be obscured at longer sampling frequencies. Nearly all earlier work has specified returns as weekly or longer [see, for example, Karemara et al. (1999), Los (2000), Abraham et al. (2002)].

The remainder of the paper is divided into four main areas. Section 2 provides a description of the data employed in the analysis. Section 3 discusses the empirical methodology used. The results are dealt with in Section 4. The paper ends with some concluding remarks in Section 5.

2. Description and Properties of the Data

The data employed in the study is composed of market value-weighted equity indices for ten emerging Asian markets – China (CHN), India (IND), Indonesia (INA), Korea (KOR), Malaysia (MLY), Pakistan (PAK), The Philippines (PHL), Sri Lanka (SRI), Taiwan (TWN) and Thailand (THA) – and five developed Asian markets – Australia (AST), Hong Kong (HKG), Japan (JPN), New Zealand (NZL) and Singapore (SNG). All data is obtained from Morgan Stanley Capital International (MSCI) and specified in US dollar terms. The series encompass dissimilar sampling periods given the varying availability of each index. The end date for all series is 28-May-2003 with AST commencing on 31-Dec-1986, PAK on 1-Nov-1995, CHN, IND and SRI on 31-Dec-1992, and the remaining markets on 31-Dec-1987.

Daily data is specified. The natural log of the relative price is computed for the daily intervals to produce a time series of continuously compounded returns, such that $r_t = \log(p_t / p_{t-1}) \times 100$, where p_t and p_{t-1} represent the stock index price at time t and t-1, respectively. Table 1 presents a summary of descriptive statistics of the daily returns for the fifteen markets. Sample means, maximums, minimums, standard deviations, skewness, kurtosis and Jacque-Bera statistics and p-values are reported. The lowest mean returns are in China (-0.0007), Pakistan (-0.0002) and Japan (-0.0002) and the highest mean returns are for Singapore (0.0001), Australia (0.0002) and Hong Kong (0.0003). The lowest minimum returns are in Australia (-0.6880) and Indonesia (-0.4308), as are the highest maximum returns (0.5935 and 0.4451, respectively). The standard deviations of returns range from 0.0133 (Singapore) to 0.0406 (Australia). On this basis, of the fifteen markets the returns in Singapore, New Zealand and Japan are the least volatile, with Korea, Indonesia and Australia being the most volatile.

<TABLE 1 HERE>

By and large, the distributional properties of all fifteen return series appear non-normal. Given that the sampling distribution of skewness is normal with mean 0 and standard deviation of $\sqrt{6/T}$ where T is the sample size, all of the return series, with the exception of Taiwan and Singapore, are significantly skewed. Australia, Hong Kong, Malaysia, Pakistan, New Zealand and India are negatively skewed, indicating the greater probability of large deceases in returns than rises, while Indonesia, China, Japan, Korea, Thailand, Philippines and Sri Lanka are positively skewed, signifying the greater likelihood of large increases in returns than falls. The kurtosis, or degree of excess, in all market returns is also large, ranging from 5.3354 for Taiwan to 146.2114 for Australia, thereby indicating leptokurtic distributions with many extreme observations. Given the sampling distribution of kurtosis is normal with mean 0 and standard deviation of $\sqrt{24/T}$ where T is the sample size, then all estimates are once again statistically significant at any conventional level. Finally, the calculated Jarque-Bera statistics and corresponding p-values in Table 1 are used to test the null hypotheses that the daily distribution of market returns is normally distributed. All p-values are smaller than the .01 level of significance suggesting the null hypothesis can be rejected. None of these market returns are then well approximated by the normal distribution.

3. Empirical Methodology

3.1 Random walk hypothesis

Consider the following random walk with drift process:

$$p_t = p_{t-1} + \beta + \varepsilon_t \quad (1)$$

or

$$r_t = \Delta p_t = \beta + \varepsilon_t \quad (2)$$

where p_t is the logarithm of the price index observed at time t, β is an arbitrary drift parameter, r_t is the change in the index and ε_t is a random disturbance term satisfying $E(\varepsilon_t) = 0$, σ_ε^2 is constant and $E(\varepsilon_t\varepsilon_{t-g}) = 0$, where $g \neq 0$, for all t. Under the random walk hypothesis, a market is (weak-form) efficient if the most recent price contains all available information and therefore the best predictor of future prices is the most current price. In the strictest version of the efficient market hypothesis, ε_t is not only random and stationary, but exhibits no autocorrelation, since the disturbance term cannot possess any systematic forecast errors.

Accordingly, and despite its apparent singularity, the random walk model actually comprises three successively more restrictive hypotheses with sequentially stronger tests for random walks (Campbell et al., 1997; Fama, 1970; 1991). The least restrictive of these is that in a market that complies with a random walk it is not possible to use information on past prices to predict future prices (hereafter RW3). That is, returns in a market conforming to RW3 are serially uncorrelated, corresponding to a random walk hypothesis with dependent but uncorrelated increments. Parametric serial correlation tests of independence and non-parametric runs tests can be used to test for serial dependence.

However, it may still be possible for information on the variance of past prices to predict the future volatility of the market. A market that conforms to these conditions implies that returns are serially uncorrelated, corresponding with a random walk hypothesis with increments that are independent but not identically distributed (hereafter RW2). Unit root tests can be used to determine if the series is difference or trend non-stationary as a necessary condition for a random walk.

Finally, if it is not possible to predict either future price movements or volatility on the basis of information from past prices, then such a market complies with the most restrictive notion of a random walk (hereafter RW1). In such a market, returns are serially uncorrelated and conform to a random walk hypothesis with independent and identically distributed increments. Multiple variance ratio tests can focus attention on the uncorrelated residuals in the series, under assumptions of both homoskedastic and heteroskedastic random walks.

3.2 Serial dependence tests

Two approaches are employed to test for serial dependence in the returns (RW1). First, the serial correlation coefficient test is a widely employed procedure that tests the relationship between returns in the current period and those in the previous period. If no significant autocorrelations are found then the series are assumed to follow a random walk. Second, the runs test determines whether successive price changes are independent and unlike the serial correlation test of independence, is non-parametric and does not require returns to be normally distributed. Observing the number of 'runs' - or the sequence of successive price changes with the same sign - in a sequence of price changes tests the null hypothesis of randomness. To perform this test A is assigned to each return that equals or exceeds the mean value and B for the items that are below the mean. Let n_A and n_B be the sample sizes of items A and B respectively. The test statistic is U, the total number of runs. For a large sample, that is where both n_A and n_B are greater than twenty, the test statistic is approximately normally distributed:

$$Z = \frac{U - \mu_U}{\sigma_U} \tag{3}$$

where

$$\mu_U = \frac{2n_A n_B}{n} + 1, \quad \sigma_U = \sqrt{\frac{2n_A n_B(2n_A n_B - n)}{n^2(n-1)}} \quad \text{and } n = n_A + n_B$$

3.3 Unit root tests

Three different unit root tests are used to test the null hypothesis of a unit root: namely, the Augmented Dickey-Fuller (ADF) test (1979), the Phillips-Peron (PP) test (1988), and the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test (1992). These correspond to tests of the next to most restrictive random walk hypothesis (RW2). To start with, the well-known ADF unit root test of the null hypothesis of nonstationarity is conducted in the form of the following regression equation:

$$\Delta p_{it} = \alpha_0 + \alpha_1 t + \rho_0 p_{it-1} + \sum_{i=1}^{q} \rho_i \Delta p_{it-i} + \varepsilon_{it} \tag{4}$$

where p_{it} denotes the logarithm of the price for the i-th market at time t, $\Delta p_{it} = p_{it} - p_{it-1}$, ρ are coefficients to be estimated, q is the number of lagged terms, t is the trend term, α_1 is the estimated coefficient for the trend, α_0 is the constant, and ε is white noise. MacKinnon's critical values are used in order to determine the significance of the test statistic associated with ρ_0.

The PP incorporates an alternative (nonparametric) method of controlling for serial correlation when testing for a unit root by estimating the non-augmented Dickey-Fuller test equation and modifying the test statistic so that its asymptotic distribution is unaffected by serial correlation. Finally, the KPSS uses a similar (though parametric) autocorrelation correction to the PP but assumes that the observed time series can be decomposed into the sum of a deterministic trend, a random walk with zero variance and a stationary error term. It thus tests the null hypothesis of trend stationarity corresponding to the hypothesis that the variance of the random walk equals zero.

Of course, it is well known that ADF unit root tests fail to reject the null hypothesis of a unit root for many time series, and that allowing for error autocorrelation using the PP test does not necessarily improve these results. However, the KPSS test complements the standard unit root tests since it can distinguish between the logarithm of the prices that appear to be stationary, those that appear to have a unit root, and those that are not sufficiently informative to be sure whether they are either.

3.4 Multiple variance ratio tests

The multiple variance ratio (MVR) test as proposed by Chow and Denning (1993) is used to detect autocorrelation and heteroskedasticity in the returns. Based on Lo and MacKinlay's (1988) single variance ratio (VR) test, Chow and Denning (1993) adjust the focus from a specific interval to one more consistent with the random walk hypothesis by means of covering all possible intervals. As shown by Lo and MacKinlay (1988), the variance ratio statistic is derived from the assumption of linear relations in observation interval regarding the variance of increments. If a series follows a random walk process, the variance of a qth-differenced variable is q times as large as the first-differenced variable. For a series partitioned into equally spaced intervals and characterised by random walks, one qth of the variance of $(p_t - p_{t-q})$ is expected to be the same as the variance of $(p_t - p_{t-1})$:

$$Var(p_t - p_{t-q}) = qVar(p_t - p_{t-1}) \tag{5}$$

where q is any positive integer. The variance ratio is then denoted by:

$$VR(q) = \frac{\frac{1}{q}Var(p_t - p_{t-q})}{Var(p_t - p_{t-1})} = \frac{\sigma^2(q)}{\sigma^2(1)} \tag{6}$$

such that under the null hypothesis $VR(q) = 1$. Chow and Denning (1993) then generate a procedure for the multiple comparison of the set of variance ratio estimates with unity. For a single variance ratio test, under the null hypothesis, $VR(q) = 1$, hence $M_r(q) = VR(q) - 1 = 0$. Consider a set of m variance ratio tests $\{M_r(q_i) \mid i = 1,2,\ldots,m\}$. Under the random walk null hypothesis, there are multiple sub-hypotheses: H_{oi}: $M_r(q_i) = 0$ for $i = 1, 2,\ldots, m$ and H_{1i}: $M_r(q_i) \neq 0$ for any $i = 1, 2,\ldots, m$. The rejection of any one or more H_{oi} rejects the random walk null hypothesis. For a set of test statistics, say $Z(q)$, $\{Z(q_i) \mid i = 1,2,\ldots,m\}$, the random walk null hypothesis is rejected if any one of the estimated variance ratio is significantly different from one. Chow and Denning (1993) control the size of the *MVR* test by comparing the calculated values of the standardized test statistics, either $Z(q)$ or $Z^*(q)$ with the Standardized Maximum Modulus (*SMM*) critical values where $Z_{\alpha^*/2}$ and $\alpha^* = 1-(1-\alpha)^{1/m}$. If the maximum absolute value of $Z(q)$ is greater than the *SMM* critical value than the random walk hypothesis is rejected.

4. Empirical Results

Table 2 presents the tests of independence: namely, the serial correlation and runs tests. All of the null hypotheses of no serial correlation for the ten emerging markets are rejected at the .01

level or higher, a similar level of significance as obtained for the developed markets of Australia, Japan and Singapore. The null hypothesis of no serial correlation is rejected at the .05 level for Hong Kong and the .10 level for New Zealand. The significance of the autocorrelation coefficient indicates that the null hypothesis of weak-form market efficiency may be rejected and we may infer that all fifteen Asian markets are weak-form inefficient over the various sample periods.

With the exception of Australia, all of the coefficients are positive indicating persistence in returns, with persistence being higher in Sri Lanka (0.2640), Indonesia (0.1850) and Thailand (0.1840) and lower in Japan (0.0480), Hong Kong (0.0300) and New Zealand (0.0250). The average persistence is 0.0577 for developed markets and 0.1421 for emerging markets. For Australia the serial correlation coefficient of -0.1721 is indicative of a mean reversion process. However, it should be noted that over shorter horizons the markets exhibiting persistence (mean-reversion) could also exhibit mean-reversion (persistence). In terms of the runs tests, the negative *z*-values for all of the markets, both emerging and developed, indicates that the actual number of runs falls short of the expected number of runs under the null hypothesis of return independence at the .05 level for Japan and at the .01 level or lower for all other markets. These indicate positive serial correlation.

<TABLE 2 HERE>

We likewise reject the null hypothesis of weak-form efficiency when employing the nonparametric assumptions entailed in the runs tests in Table 2. By way of comparison, Karemera et al. (1999) used monthly data and runs tests to conclude that only the Philippines, Singapore, Taiwan and Thailand were not weak-form efficient from an international investor's perspective (when measured in US dollars) while Hong Kong, Korea, Indonesia, Malaysia and Thailand were weak-form efficient on this basis. Poshakwale (1996) also rejected the null hypothesis of weak form efficiency using runs tests, though only for the Indian market

Table 3 illustrates the unit root tests, comprising the ADF and PP *t*-statistics and *p*-values and the KPSS *LM*-statistic and asymptotic significance at the level and difference series of the logarithm of prices. In the case of the former the null hypothesis of a unit root is tested against the alternative of no unit root (stationary). For the latter, the null hypothesis of no unit root is tested against the alternative of a unit root (non-stationary). At levels, the ADF and PP *t*-statistics do not reject the null hypotheses of a unit root at the 0.05 level of significance or lower, with the exception of the Australian (AST) and Taiwan (TWN) markets for the PP test, thereby indicating that almost all of the logarithms of the price series examined are non-stationary.

<TABLE 3 HERE>

For the KPSS tests of the null hypothesis of no unit root, the *LM*-statistic exceeds the asymptotic critical value at the .01 level for all markets at the level series, indicating these series are non-stationary with the exception of Taiwan (TWN). As a necessary condition for a random walk, the ADF and PP unit root tests did not reject the requisite null hypothesis in the case of all fifteen emerging and developed markets with the exception of Australia and Taiwan, while the KPSS unit root tests reject the required null with the exception of Taiwan at the .01 level. Since the ADF, PP and KPSS tests on the log of prices fail to reject the presence of unit roots, there is no evidence against weak form efficiency for all markets, except in Australia and Taiwan. That said, since it is well known that unit root tests have very poor power properties, a preferred alternative is multiple variance ratio tests.

Table 4 presents the results of the multiple variance ratio tests of returns in the ten emerging and five developed Asian equity markets. The sampling intervals are 2, 5, 10 and 20 days, corresponding to one-day, one week, one fortnight and one month calendar periods. For each interval Table 4 presents the estimates of the variance ratio *VR(q)* and the test statistics for the null hypotheses of homoskedastic, *Z(q)* and heteroskedastic, *Z*(q)* increments random walk. Under the multiple variance ratio procedure, only the maximum absolute values of the test statistics are examined. For sample sizes exceeding at least 1,975 observations (Pakistan) and where $m = 4$, the critical value for these test statistics is 2.49 at the .05 level of significance. For each set of multiple variance ratio tests, an asterisk denotes the maximum absolute value of the test statistic that exceeds this critical value and thereby indicates whether the null hypothesis of a random walk is rejected.

<TABLE 4 HERE>

Consider the results for Australia. The null hypothesis that daily equity returns follow a homoskedastic random walk is rejected at Z(5) = -15.5281. Rejection of the null hypothesis of a random walk under homoskedasticity for a 5-day period is also a test of the null hypothesis of a homoskedastic random walk under the alternative sampling periods and we may therefore conclude that Australian equity returns do not follow a random walk. However, rejection of the null hypothesis under homoskedasticity could result from heteroskedasticity and/or autocorrelation in the return series. After a heteroskedastic-consistent statistic is calculated, the null hypothesis is also rejected at Z*(10) = -3.3044. The heteroskedastic random walk hypothesis is thus rejected because of autocorrelation in the daily increments of the returns on Australian equity. We may conclude that the Australian equity market is not weak form efficient.

Further, Lo and MacKinlay (1988) show that for $q = 2$, estimates of the variance ratio minus one and the first-order autocorrelation coefficient estimator of daily price changes are asymptotically equal [Australia's serial correlation coefficient in Table 2 is -0.1720]. On this basis, the estimated first order autocorrelation coefficient is -0.1716 corresponding to the estimated variance ratio $V\hat{R}(2)$ of 0.8284 (i.e. 0.8284 - 1.0000). In addition, where $V\hat{R}(2) < 1$

a mean reverting process is indicated whereas when $V\hat{R}(2) > 1$ persistence is suggested. This indicates there is negative autocorrelation (or mean reversion) in Australian equity returns over the long horizon.

By way of comparison, observe the results for Hong Kong. At none of the sampling intervals are the test statistics for the null hypotheses of homoskedastic, *Z(q)* and heteroskedastic, *Z*(q)* random walks greater than the critical value of 2.49. This suggests that the Hong Kong equity market is weak form efficient. Alternatively, in the case of Malaysia the null hypotheses of a homoskedastic random walk is rejected [*Z(q)*=5.8880], but the null hypothesis of a heteroskedastic random walk is not [*Z*(q)*=1.9006]. This indicates that rejection of the null hypothesis of a homoskedastic random walk could be the result, at least in part, of heteroskedasticity in the returns, and cannot be assigned exclusively to the autocorrelation in returns.

Of the ten emerging markets, the null hypothesis of a random walk under assumptions of both homoskedasticity and heteroskedasticity is rejected for all except Korea and Malaysia. We may then conclude that none of these markets are weak form efficient. With Korea and Malaysia the null hypothesis of a homoskedastic random walk is rejected, but not that for a heteroskedastic random walk. This infers that the random walk violation could be the result of heteroskedasticity and/or autocorrelation in daily returns. The multiple variance ratio technique also indicates the presence of positive autocorrelation (or persistence) in all the emerging markets and thereby provides comparable evidence to the results of the serial correlation coefficient and runs tests.

As noted, few studies exist by which a direct comparison of results can be made, primarily because most specified monthly rather than daily returns. Karemera et al. (1999) concluded that domestic investors would perceive Indonesia, Korea, Malaysia, Philippines, Taiwan and Thailand as following a random walk under Chow and Denning's (1993) multiple variance ratio procedure, with Korea, Malaysia and Taiwan following a random walk under Lo and MacKinlay's (1988) earlier single variance ratio approach. More recently, Ryoo and Smith (2002) found that as price limits were removed for individual securities, the Korean market progressively approached a random walk, while Lee et al. (2001) concluded that random walks could be rejected in all of China's stock exchanges on the basis of variance ratio tests.

With regard to the developed markets, Australia and Singapore reject the null hypothesises of a homoskedastic and heteroskedastic random walk, Japan rejects the null hypothesis of a homoskedastic but not a heteroskedastic random walk, while Hong Kong and New Zealand fail to reject the null hypotheses of either a homoskedastic or heteroskedastic random walk. This indicates that only in the case of Hong Kong and New Zealand may we infer the unqualified presence of weak-form market efficiency, while in Japan the rejection of the strictest version of the random walk hypothesis is complicated by the presence of heteroskedasticity. This confirms the findings of Cheung and Coutts (2001) who likewise concluded that the Hong Kong market followed a random walk and was therefore weak form efficient.

5. Conclusion

This paper examines the weak form market efficiency of fifteen Asian equity markets, of which ten are regarded as emerging and the remainder as developed. Three different procedures are employed to test for random walks in daily returns: (i) the parametric serial correlation coefficient and the nonparametric runs test are used to test for serial correlation (RW1); (ii) Augmented Dickey-Fuller, Phillips-Perron and Kwiatkowski, Phillips, Schmidt and Shin unit root tests are used to test for non-stationarity as a necessary condition for a random walk (RW2); and (iii) multiple variance test statistics are used to test for random walks under varying distributional assumptions (RW3). The results for the tests of serial correlation are in broad agreement, conclusively rejecting the presence of random walks in daily returns in both emerging and developed markets. Contrary to the serial correlation tests, the unit root tests conclude that unit roots, as necessary conditions for a random walk, are evident in nearly all logs of the price series. Finally, the multiple variance ratio procedure conclusively rejects the presence of random walks in any emerging market. Among the developed markets, only Hong Kong and New Zealand satisfy the most stringent random walk criteria with Japan meeting at least some of the requirements of a strict random walk.

The serial correlation and runs tests suggest that the Asian markets are weak form inefficient, while the three unit roots tests indicate the contrary with the exception of Australia and Taiwan. The results of the most stringent multiple variance ratio tests are consistent with the generalisation that emerging markets are unlikely to be associated with the random walks required for the assumption of weak-form market efficiency. However, the evidence regarding developed markets is less conclusive with some markets following random walks while others do not. Furthermore, the results offer contradictory evidence to earlier work using a variety of tests for random walks, of which the most likely contributory factor in those instances is the use of weekly and monthly sampling frequencies, rather than any variation in testing procedure. That said, apart from multiple variance ratio tests, care should be taken when interpreting findings obtained using these other procedures, especially simple unit root tests.

There are, of course, a number of ways in which this research could be extended. One possible extension would be to use the multiple variance ratio test procedure in conjunctions with intraday data. While Ronen (1997) and Andersen et al. (2001) have shown that the single variance ratio test is not robust and can be misleading in a high-frequency context, no such evidence concerns the multiple variance ratio test. A second extension would be to examine more fully the relationship between the evolving characteristics of Asian stock markets and market efficiency. It is generally known that weak form inefficiency is linked with the newer, small capitalisation markets with low levels of liquidity and turnover but little is known about how quickly markets approach a random walk as they become more liquid and institutionally mature. Stock level data in developed markets may be able to throw some light on this question with the contrast between large and small capitalisation stocks, as would the decomposition of the data used in this analysis into shorter periods.

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Table 1
Descriptive statistics for Asian emerging and developed markets

Market	Start	End	Observations	Mean	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	JB *p*-value
CHN	31-Dec-1992	28-May-2003	2714	-6.92E-04	0.1274	-0.1444	0.0206	0.1499	7.8377	2.66E+03	0.0000
IND	31-Dec-1992	28-May-2003	2714	-5.51E-05	0.0886	-0.0896	0.0160	-0.1047	5.9132	9.65E+02	0.0000
INA	31-Dec-1987	28-May-2003	4019	4.63E-05	0.4451	-0.4308	0.0287	0.1186	46.3110	3.14E+05	0.0000
KOR	31-Dec-1987	28-May-2003	4019	4.10E-05	0.2688	-0.2167	0.0238	0.3767	15.3820	2.58E+04	0.0000
MLY	31-Dec-1987	28-May-2003	4019	1.19E-04	0.2585	-0.3697	0.0196	-0.7903	60.5769	5.56E+05	0.0000
PAK	1-Nov-1995	28-May-2003	1975	-1.82E-04	0.1421	-0.1573	0.0218	-0.4492	9.3993	3.44E+03	0.0000
PHL	31-Dec-1987	28-May-2003	4019	-4.53E-05	0.2197	-0.1094	0.0174	0.7072	15.8291	2.79E+04	0.0000
SRI	31-Dec-1992	28-May-2003	2714	-1.34E-04	0.2758	-0.1014	0.0149	2.5955	50.4735	2.58E+05	0.0000
TWN	31-Dec-1987	28-May-2003	4019	1.14E-04	0.1265	-0.1113	0.0213	0.0214	5.3354	9.14E+02	0.0000
THA	31-Dec-1987	28-May-2003	4019	-2.61E-05	0.1810	-0.1444	0.0216	0.6936	12.3500	1.50E+04	0.0000
AST	31-Dec-1986	28-May-2003	4280	1.87E-04	0.5935	-0.6880	0.0406	-4.8805	146.2114	3.67E+06	0.0000
HKG	31-Dec-1987	28-May-2003	4019	2.64E-04	0.1601	-0.2619	0.0169	-1.0146	25.1574	8.29E+04	0.0000
JPN	31-Dec-1987	28-May-2003	4019	-1.75E-04	0.1227	-0.0841	0.0146	0.3444	7.1163	2.92E+03	0.0000
NZL	31-Dec-1987	28-May-2003	4019	-4.20E-05	0.1103	-0.1576	0.0141	-0.3406	11.0664	1.10E+04	0.0000
SNG	31-Dec-1987	28-May-2003	4019	1.55E-04	0.1185	-0.1076	0.0133	0.0222	11.6198	1.24E+04	0.0000

Notes: Emerging markets: CHN – China, IND – India, INA – Indonesia, KOR – Korea, MLY – Malaysia, PAK – Pakistan, PHL – Philippines, SRI – Sri Lanka, TWN – Taiwan, THA – Thailand. Developed markets: AST – Australia, HKG – Hong Kong, JPN – Japan, NZL – New Zealand, SNG - Singapore; JB – Jarque-Bera. Critical values for significance of skewness and kurtosis respectively at the .05 level are 0.0921 and 0.1843 for CHN, IND and SRI, 0.0757 and 0.1515 for INA, KOR, MLY, TWN, THA, HKG, JPN, NKL and SNG, 0.1080 and 0.2161 for PAK and 0.0733 and 0.1467 for AST.

Table 2
Independence tests for Asian emerging and developed markets

Market	Serial correlation		Runs test						
	Coefficient	*p*-value	Mean	Cases < mean	Cases ≥ mean	Total cases	Number of runs	Runs Z-value	*p*-value
CHN	0.1800	0.0000	-6.92E-04	1348	1366	2714	1181	-6.7944	0.0000
IND	0.1340	0.0000	-5.51E-05	1302	1412	2714	1147	-8.0295	0.0000
INA	0.1850	0.0000	4.63E-05	2064	1955	4019	1745	-8.3365	0.0000
KOR	0.0730	0.0000	4.10E-05	2171	1848	4019	1837	-5.0977	0.0000
MLY	0.0920	0.0000	1.19E-04	2040	1979	4019	1763	-7.7963	0.0000
PAK	0.0700	0.0009	-1.82E-04	869	1106	1975	906	-3.1185	0.0018
PHL	0.1790	0.0000	-4.53E-05	1940	2079	4019	1777	-7.3003	0.0000
SRI	0.2640	0.0000	-1.34E-04	1292	1422	2714	1079	-10.6178	0.0000
TWN	0.0600	0.0001	1.14E-04	2139	1880	4019	1911	-2.8881	0.0039
THA	0.1840	0.0000	-2.61E-05	1958	2061	4019	1767	-7.6463	0.0000
AST	-0.1720	0.0000	1.87E-04	2139	2141	4280	2033	-3.3020	0.0010
HKG	0.0300	0.0286	2.64E-04	2097	1922	4019	1905	-3.2146	0.0013
JPN	0.0480	0.0012	-1.75E-04	2035	1984	4019	1941	-2.1830	0.0290
NZL	0.0250	0.0565	-4.20E-05	1957	2062	4019	1913	-3.0351	0.0024
SNG	0.1280	0.0000	1.55E-04	2000	2019	4019	1831	-5.6623	0.0000

Notes: Emerging markets: CHN – China, IND – India, INA – Indonesia, KOR – Korea, MLY – Malaysia, PAK – Pakistan, PHL – Philippines, SRI – Sri Lanka, TWN – Taiwan, THA – Thailand. Developed markets: AST – Australia, HKG – Hong Kong, JPN – Japan, NZL – New Zealand, SNG – Singapore.

Table 3
Unit root tests for Asian emerging and developed markets

Market	Level		Difference		Level		Difference		Level		Difference	
	ADF *t*-statistic	ADF *p*-value	ADF *t*-statistic	ADF *p*-value	PP *t*-statistic	PP *p*-value	PP *t*-statistic	PP *p*-value	KPSS *LM*-statistic	KPSS significance	KPSS *LM*-statistic	KPSS significance
CHN	-0.8120	0.8151	-43.4190	0.0000	-0.7555	0.8306	-43.2207	0.0000	5.9522	0.0100	0.0395	-
IND	-2.1261	0.2344	-45.5071	0.0001	-2.0892	0.2492	-45.5698	0.0001	0.9207	0.0100	0.0784	-
INA	-1.3241	0.6205	-27.0920	0.0000	-1.3887	0.5894	-52.2579	0.0001	3.8200	0.0100	0.3360	-
KOR	-2.1096	0.2410	-19.9232	0.0000	-2.1864	0.2114	-58.7273	0.0001	1.4078	0.0100	0.0691	-
MLY	-1.8086	0.3767	-26.7006	0.0000	-1.9145	0.3258	-57.7089	0.0001	1.0652	0.0100	0.2252	-
PAK	-1.6106	0.4769	-41.3760	0.0000	-1.7596	0.4010	-42.0646	0.0000	3.0615	0.0100	0.1760	-
PHL	-0.8497	0.8042	-52.7718	0.0001	-0.8561	0.8023	-52.5846	0.0001	1.7749	0.0100	0.7687	0.0100
SRI	-1.0677	0.7305	-39.7470	0.0000	-1.1639	0.6921	-40.9057	0.0000	5.0127	0.0100	0.1410	-
TWN	-2.9705	0.0378	-59.6276	0.0001	-3.0367	0.0317	-59.8063	0.0001	0.4037	0.1000	0.2482	-
THA	-1.0626	0.7325	-52.5932	0.0001	-0.9995	0.7556	-52.4066	0.0001	3.6711	0.0100	0.4008	0.1000
AST	-2.4242	0.1351	-13.3394	0.0000	-4.9420	0.0000	-	-	6.6590	0.0100	0.0545	-
HKG	-2.0221	0.2774	-34.3015	0.0000	-2.0841	0.2513	-61.4743	0.0001	5.3948	0.0100	0.3250	-
JPN	-1.2264	0.6652	-60.3652	0.0001	-1.1308	0.7058	-60.3678	0.0001	3.0444	0.0100	0.1143	-
NZL	-1.8018	0.3800	-61.8156	0.0001	-1.8587	0.3523	-61.8230	0.0001	0.9566	0.0100	0.0972	-
SNG	-2.4685	0.1234	-55.6385	0.0001	-2.4526	0.1275	-55.5400	0.0001	2.6277	0.0100	0.4166	0.1000

Notes: Emerging markets: CHN – China, IND – India, INA – Indonesia, KOR – Korea, MLY – Malaysia, PAK – Pakistan, PHL – Philippines, SRI – Sri Lanka, TWN – Taiwan, THA – Thailand. Developed markets: AST – Australia, HKG – Hong Kong, JPN – Japan, NZL – New Zealand, SNG – Singapore. For Augmented Dickey-Fuller (ADF) test hypotheses are H_0: unit root, H_1: no unit root (stationary). The lag orders in the ADF equations are determined by the significance of the coefficient for the lagged terms. Intercepts only in the series. The Phillips-Peron (PP) unit root test hypotheses are H_0: unit root, H_1: no unit root (stationary). Intercepts only in the series. The Kwiatkowski, Phillips, Schmidt and Shin (KPSS) unit root test hypotheses are H_0: no unit root (stationary), H_1: unit root. The asymptotic critical values for the KPSS LM test statistic at the .10, .05 and .01 levels are 0.3470, 0.4630 and 0.7390 respectively.

Table 4
Multiple variance ratio tests for Asian emerging and developed markets

Market	Statistics	q = 2	q = 5	q = 10	q = 20	Market	Statistics	q = 2	q = 5	q = 10	q = 20	Market	Statistics	q = 2	q = 5	q = 10	q = 20
CHN	VRq	1.1805	1.3272	1.3081	1.4551	PAK	VRq	1.0717	1.2034	1.3401	1.5342	AST	VRq	0.8284	0.4800	0.2887	0.1728
	Zq	*9.4053	7.7807	4.7532	4.7705		Zq	3.1850	4.1249	4.4767	*4.7767		Zq	-11.2281	*-15.5281	-13.7823	-10.8883
	Z*q	*5.5254	4.8829	3.1739	3.3900		Z*q	2.2264	2.7516	3.0597	*3.3991		Z*q	-1.9968	-3.1771	*-3.3044	-3.0368
IND	VRq	1.1347	1.2674	1.3008	1.4189	PHL	VRq	1.1816	1.3061	1.3347	1.5881	HKG	VRq	1.0307	1.0629	1.0251	1.1108
	Zq	*7.0171	6.3577	4.6420	4.3912		Zq	*11.5136	8.8576	6.2843	7.5022		Zq	1.9472	1.8214	0.4711	1.4130
	Z*q	*5.2580	4.7768	3.5559	3.4763		Z*q	*6.1956	5.1894	3.9776	5.0838		Z*q	0.9458	0.9476	0.2542	0.8051
INA	VRq	1.1863	1.3268	1.2810	1.4412	SRI	VRq	1.2646	1.5524	1.8235	2.0574	JPN	VRq	1.0491	1.0244	0.9564	0.9727
	Zq	*11.8110	9.4556	5.2762	5.6282		Zq	*13.7825	13.1355	12.7055	11.0840		Zq	*3.1123	0.7073	-0.8182	-0.3478
	Z*q	*3.2535	2.9189	1.7275	2.0253		Z*q	6.8487	*7.0220	6.8004	6.5137		Z*q	2.4381	0.5506	-0.6335	-0.2757
KOR	VRq	1.0740	1.0164	0.9255	1.0246	TWN	VRq	1.0614	1.1812	1.2226	1.3759	NZL	VRq	1.0254	1.0230	1.0131	1.0680
	Zq	*4.6891	0.4738	-1.3979	0.3136		Zq	3.8896	*5.2418	4.1790	4.7952		Zq	1.6084	0.6649	0.2453	0.8670
	Z*q	2.3758	0.2243	-0.6490	0.1474		Z*q	2.9760	*3.8226	3.0566	3.5432		Z*q	0.8321	0.3899	0.1622	0.6399
MLY	VRq	1.0929	1.1896	1.1459	1.1864	THA	VRq	1.1849	1.3216	1.3007	1.4653	SNG	VRq	1.1300	1.2279	1.2284	1.3182
	Zq	*5.8880	5.4877	2.7393	2.3779		Zq	*11.7214	9.3069	5.6452	5.9350		Zq	*8.2400	6.5934	4.2891	4.0587
	Z*q	1.8517	1.9006	1.0602	1.0158		Z*q	*6.3203	5.0496	3.2070	3.5353		Z*q	*4.0408	3.3821	2.3671	2.4568

Notes: Emerging markets: CHN – China, IND – India, INA – Indonesia, KOR – Korea, MLY – Malaysia, PAK – Pakistan, PHL – Philippines, SRI – Sri Lanka, TWN – Taiwan, THA – Thailand. Developed markets: AST – Australia, HKG – Hong Kong, JPN – Japan, NZL – New Zealand, SNG – Singapore. VR(q) – variance ratio estimate, Z(q) - test statistic for null hypothesis of homoskedastic increments random walk, Z* (q) - test statistic for null hypothesis of heteroskedastic increments random walk; the critical value for Z(q) and Z*(q) at the 5 percent level of significance is 2.49, an asterisk indicates significance at this level; Sampling intervals (q) are in days.