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Random Walks and Market Efficiency Tests: Evidence from Emerging Equity Markets

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Abstract. We use the multiple variance-ratio test of Chow and Denning (1993) to examine the stochastic properties of local currency- and US dollar-based equity returns in 15 emerging capital markets. The technique is based on the Studentized Maximum Modulus distribution and provides a multiple statistical comparison of variance-ratios, with control of the joint-test's size. We find that the random walk model is consistent with the dynamics of returns in most of the emerging markets analyzed, which contrasts many random walk test results documented with the use of single variance-ratio techniques. Further, a runs test suggests that most of the emerging markets are weak-form efficient. Overall, our results suggest that investors are unlikely to make systematic nonzero profit by using past information in many of the examined markets, thus, investors should predicate their investment strategies on the assumption of random walks. Additionally, our results suggest exchange rate matters in returns' dynamics determination for some of the emerging equity markets we analyzed.

Key words: random walk, stock prices, multiple variance-ratio test, emerging capital markets, weak-form efficiency

JEL Classification: G15, G14

Introduction

The random walk properties of security prices have an important bearing on the determination of security return dynamics and on associated potential trading strategies, as is amply suggested by Poterba and Summers (1988, pp. 53–54), Lo and MacKinlay (1989), and Eckbo and Liu (1993). Random walks, which are a special case of unit root processes, help identify the kinds of shocks that drive stock prices. If a given equity price series is, for instance, a random walk, the generating process is dominated by permanent components and hence has no mean-reversion tendency.[1] A shock to the series from an initial equilibrium will lead to increasing deviations from its long-run equilibrium. Moreover, the random walk properties of stock returns are considered an outcome of the efficient market hypothesis (i.e., stock prices exhibit unpredictable behavior, given available information). Accordingly, Liu and Maddala (1992) demonstrate how the presence or absence of random walks in security returns is crucial to both the formulation of rational expectation models and the testing of market efficiency hypothesis.

Several studies, (e.g., Hakkio (1986), Summer (1986), Fama and French (1988), and Poterba and Summers (1988)) demonstrate that standard random walk hypothesis

(RWH)[2] tests (e.g., unit root tests) lack power and are, thus, unable to reject the RWH against a stationary alternative when the hypothesis is, in fact, false. To resolve this shortcoming, Lo and MacKinlay (1988) (hereafter LOMAC) developed tests for random walk based on variance ratio estimators. Generally, variance ratio tests focus on the uncorrelatedness of variance increments because there are departures from random walks that unit root tests cannot detect. The LOMAC test is essentially a single-test of unity for each variance ratio, but the variance ratio approach to testing random walks requires that all ratios be unity. In other words, the LOMAC test ignores the joint nature of the hypothesis and may lead to inaccurate inferences. To bridge that gap and more, Chow and Denning (1993) (hereafter CHODE) designed a multiple variance ratio test which explores the unity of all variance ratios simultaneously as in a classic joint F-test. The test controls the size of the joint-test by using the Studentized Maximum Modulus (SMM) distribution theory. Although CHODE's test is conservative by design (i.e., critical values are large), it has the same or more power than the conventional unit root tests such as those of Dickey-Fuller (1979, 1981) or Phillips-Perron (1988). In fact, CHODE's (1993) simulation tests show that a failure to control the joint-test size leads to a large probability of Type-1 error; approximately 6, 4 and 3 times as large as the nominal size at 1%, 5% and 10% significance levels, respectively. This type of improvement on RWH test techniques has particularly become important in light of results from recent tests of equity price dynamics that are increasingly showing equity prices as the sum of a random walk and a stationary transitory (and often predictable) component (Eckbo and Liu (1993)).

Applications of the above-mentioned methodological advances in testing for random walks in stock prices have been limited to major stock markets of developed countries (e.g., see Fama and French (1988), Poterba and Summer (1988), Lo and MacKinlay (1988), Liu and He (1992), and Eckbo and Liu (1993)). A few studies, including Claessens, Dasgupta and Glen (1993), Harvey (1994), and Urrutia (1995), investigated some dynamics-related issues in the equity series of emerging capital markets. Specifically, Claessens, Dasgupta and Glen (1993) used US dollar-based monthly equity series and LOMAC's single variance ratio test to examine market efficiency and the dynamics of emerging markets' equity returns, with emphasis on the seasonality of the returns. They found significant autocorrelation for ten of the twenty emerging markets they studied, suggesting potential predictability of many emerging equity markets. Further, their variance ratio tests rejected the RWH for only seven of the twenty markets. Their variance ratio result contrasts with that of Urrutia (1995), who similarly employed LOMAC's single variance ratio tests, but used local currency-based monthly equity series. Urrutia examined four Latin American emerging equity markets (i.e., Argentina, Brazil, Chile and Mexico) for both market efficiency and the RWH. He documents that though these four markets were weak-form efficient, they exhibited dynamics that were inconsistent with the RWH. Given that Claessens Dasgupta and Glen's study included the same four markets Urrutia examined, a suspicion on the role of exchange rate in tests of equity series' dynamics is raised. Therefore, in addition to applying the improved RWH tests to emerging market assets, we also examine whether there is an exchange rate effect in the determination of an equity returns' dynamics.

Furthermore, Harvey (1994) documents that equity returns of emerging markets are highly predictable and have low correlations with equity returns of developed markets. He, therefore, concludes that emerging equity markets are less efficient than developed markets, and that higher returns and lower risk can be obtained by incorporating emerging market equities in investors' portfolios. Given the economic implications (e.g., potential trading strategies) of the RWH and the increasing importance of emerging market assets as investment vehicles, we used the most recent multiple variance ratio test of CHODE to analyze the stochastic properties of equity returns in 15 emerging markets. Additionally, we used a runs test to identify and compare basic market efficiency across the selected emerging markets.

In brief, the objectives of our study are (1) to examine the RWH for stock prices in 15 emerging markets, including Argentina, Brazil, Chile, Hong Kong, Indonesia, Israel, Jordan, Korea, Malaysia, Mexico, Philippines, Singapore, Taiwan, Thailand, and Turkey; 2) to determine whether exchange rates affect tests of asset price dynamics; and (3) to test for basic market efficiency across the selected emerging markets. The main significance of our study of these objectives is the use of the latest test methodologies in analyzing an investment area that is growing in popularity (i.e. the emerging capital markets).

The empirical results indicate that, when we used exchange rate-adjusted data, the RWH was consistent with the dynamics of equity returns in 10 of the 15 emerging markets analyzed, and inconsistent with the remaining 5 markets. Conversely, when we used local currency-based data, some equity series yielded results that contrasted result from exchange rate-adjusted data. This lends credence to the suspicion that exchange rate effects are important in the determination of international equity returns' dynamics. Further, the RWH seems to be sensitive to the test observation intervals of the series, and the testing methodology used (i.e., single versus multiple variance ratio techniques). Specifically, comparing CHODE and LOMAC methods leads to an interesting conclusion. The former method highlights the incorrect rejections that arise when we compare the test statistics of the latter method with the critical values of the standard normal distribution, instead of appropriately comparing them to the SMM distribution critical values. Thus, the CHODE's method suggests that inferences from the LOMAC statistics should be used with caution. Additionally, our finding on exchange rate effects suggests that international investors should use exchange rate-adjusted data when determining the dynamics of their investment assets in emerging (foreign) markets. Such proper asset dynamics determination would, in turn, permit the formation of appropriate trading (or investment) strategies.

For the remainder of the paper, we first state the specifications of LOMAC's single variance ratio hypothesis and CHODE's multiple variance ratio hypothesis in Section 2. Further, we describe the pertinent data used for the study in this section. In Section 3, we present and interpret the variance ratio tests' and the market efficiency test's results; especially in light of the exchange rate effects. In Section 4, we explore the economic implications of the results of our two tests. Finally, we restate our findings and conclude the report in Section 5.

Methodology and data

LOMAC variance ratio tests

The variance ratio tests originated from the pioneering work of Lo and MacKinlay (1988) (LOMAC). Subsequently, Chow and Denning (1993) (CHODE) modified and extended the methodology. The specifications (outlines) of LOMAC's and CHODE's tests are, summarily, stated below. Let S_t denote the log of the equity return series under consideration at time t. The hypothesis of pure random walk is given by the recursive equation:

$$S_t = \mu + S_{t-1} + u_{t,} \tag{1}$$

where μ is a drift parameter and u_t is a random error term. The usual stochastic assumption on u_t is that of a Gaussian error structure, $E(u_t) = 0$ and $E(u_t{}^2) = \sigma_u{}^2$. LOMAC developed tests of random walks under alternative assumptions of homoskedasticity and heteroskedasticity on u_t.

The essence of the test is quite simple. LOMAC exploit the fact that under the RWH the increments in asset price series are serially uncorrelated and that variance of the increments increase linearly in the sampling intervals. Suppose a series of $nq + 1$ asset price observations $S_0, S_1, S_2, S_3, \ldots, S_{nq}$ at equally spaced intervals is available. If the series follows a random walk, the variance of the qth difference would be equal to q times the variance of first differences. For example, for weekly data, if random walk is the true process generating the stock price series, the variance of the weekly series should be five times the variance of a daily series. Mathematically, if model (1) describes the process generating the series, the variance of the first differences, denoted as

$$s_1^2 = \mathrm{var}(S_t - S_{t-1}), \tag{2}$$

increases linearly such that the variance of the qth differences is

$$s_q^2 = \mathrm{var}(S_t - S_{t-q}) = q\ \mathrm{var}(S_t - S_{t-1}), \tag{3}$$

where ''var'' stands for variance operator.

LOMAC provides a single test of this hypothesis by testing the null hypothesis that the ratio of variances,

$$VR(q) = \frac{1}{q}\frac{\sigma_q^2(q)}{\sigma_1^2(q)} = 1.0. \tag{4}$$

They tested this hypothesis under both the homoskedastic and heteroskedastic specifications of the variances. The variance ratio test techniques are to test the RWH mainly for two desirable statistical properties. First, LOMAC derived the asymptotic distribution of the variance ratio estimators and formulated an asymptotic standard normal test, Z, to indicate the statistical significance of the variance ratios. Second, they provided an alternative statistic, Z^* that is robust to heteroskedasticity and non-normal disturbances. Given these attributes and the ease of computation and interpretation, variance ratio tests are appealing, especially to practitioners.

Additionally, the variance ratio test statistics use overlapping observations and, consequently, achieve better efficiency and power than the Dickey-Fuller (1979, 1981) test statistics. Lo and MacKinlay (1989) used Monte Carlo experiments to show that the variance ratio test statistics are more powerful than the traditional Box-Pierce statistics. Liu and He (1991) corroborated the above result by demonstrating that variance ratio tests are as powerful as, or more powerful, than both the Box-Pierce and Dickey-Fuller tests when testing for random walks against other well known alternatives, such as AR (1), ARIMA (1, 1, 0) and ARIMA (1, 1, 1). See LOMAC (1988) for additional details on the single variance ratio derivation.

Multiple variance ratio tests

The single variance ratio approach is appropriate for testing individual variance ratios for a specific aggregation interval, q. Single variance ratio tests compare test statistics, $Z(q)$ and $Z^*(q)$ with the critical values of the standard normal tables. However, the RWH requires that variance ratios for all observation intervals, q's, be simultaneously equal to 1.0. The CHODE approach provides a multiple comparison of variance ratios with control of the test size. This approach is based on the studentized maximum modulus (SMM) distribution, and its test specifications are summarized below. Recall that the variance ratio minus one, $M_r(q)$, can be rewritten as

$$Mr(q) = \frac{\sigma_q^2(q)}{q\sigma_1^2(q)} - 1.0. \tag{5}$$

Now consider a set of m variance ratio estimates, $M_r(q_i)$ for $i = 1, 2, .., m$ corresponding to selected values of the aggregation (observation) intervals, q_i. Under the proper random walk test specification, multiple hypotheses arise as:

$$\begin{aligned} &\text{Test} \quad H_{oi} : M_r(q_i) = 0 \qquad \text{for } i = 1, 2, \ldots, m, \\ &\text{Vs.} \quad H_{1i} : M_r(q_i) \neq 0 \qquad \text{for any } \ i. \end{aligned} \tag{6}$$

The CHODE procedure applies the Sidak (1967) probability inequality and the results in Hochberg (1974) and Richmond (1982) to control the size of the multiple variance ratio test. Rejection of H_{oi} (in equation (6)) will result in the rejection of the RWH. The upper α point of the studentized maximum modulus distribution, SMM (α, m, N), with parameter m and N degrees of freedom (the number of observations) is used instead of the critical values of the standard normal distribution. Asymptotically, when $N = \infty$, the Hochberg inequality is equivalent to the Sidak inequality and SMM $(\alpha, m, \infty) = Z_\alpha{}^+/2$, where $\alpha^+ = 1 - (1 - \alpha)^{1/m}$. CHODE's method controls the size of the multiple variance ratio tests by comparing the LOMAC Z or Z^* statistics with the SMM distribution critical values. Further details on the SMM distribution and derivation of the multiple variance ratio hypothesis are available in CHODE (1993).

Data used for the study

The main data comprises monthly national stock price indices expressed in both domestic (local) currency and the US dollars for 15 emerging markets. These national stock indices are obtained from Morgan Stanley International Capital (MSIC) files for emerging markets. Eleven of the fifteen series cover the period from 1987:12 to 1997:5, while the remaining 4 run a little longer from 1986:1 to 1995:4. The MSIC stock indices are value-weighted (more like the international financial corporation, IFC indices)[3] and are adjusted for dividend payments. Given the recent nature of research interest in emerging capital markets, we provide some descriptive statistics on returns of the stock indices we examined. This provides additional information and facilitates comparison with current similar studies.

Table 1a contains basic statistics of the 15 US dollar-based return series we analyzed. The study period's mean monthly returns from investing in a fund representative of these emerging markets' stock indices range from 2.73% for Argentina to 0.14% Israel. The standard deviation (a measure of the asset's risk) ranges from 19.50% for Brazil to 4.79% for Jordan. These 15 indices have an approximate Sharpe ratio average of 0.15 with Chile, Mexico, Malaysia, Argentina, Philippines, Indonesia, Hong Kong and Thailand recording Sharpe ratios above the average of 0.15.[4] The Studentized Ranges, many of which are above 6.0 (in keeping with Fama (1976)), suggest that most of the 15 emerging markets' returns are not normally distributed. These basic characteristics agree with findings by Claessens et al. (1993), Gooptu (1993), and Harvey (1994), among others.

The statistical descriptions presented in Table 1a are replicated for the local currency-based data and presented in Table 1b. The relative ranking of mean returns in Table 1a is generally maintained in Table 1b. Note that on a risk-adjusted basis, local investors would reap higher returns from their emerging markets' equity investment than would international investors. Local investors' average Sharpe ratio is 0.22 versus 0.15 for international investors. Similarly, the studentized ranges indicate that local emerging equity returns exhibit non-normal distribution. For detailed statistical description of emerging markets' returns and their comparison with industrial markets' returns, see Errunza and Losq (1985), Claessens, Dasgupta and Glen (1993), and Harvey (1994). The emerging markets we selected for this study are among the most active markets in their region as far as foreign investors are concerned (e.g., see investment sections of The Wall Street Journal, London Financial Times or The Economist).

Results and interpretations

Results of the variance ratio tests (LOMAC and CHODE) performed on the 15 emerging markets' stock price indices are discussed below. A comparison of these results with those of previous research is also presented here and in subsequent sections.

Table 1a. Descriptive statistics of US dollar based monthly equity returns of fifteen emerging markets

Country Period	Mean Return	Standard Deviation	Standardized Return	Min (R)	Max [R]	Studentized Range
Argentina						
1987–1997	2.73	17.49	0.16	− 48	67	6.57
Brazil						
1987–1997	1.78	19.50	0.09	− 109	59	8.62
Chile						
1987–1997	2.51	6.88	0.36	14	20	4.94
Hong Kong						
1986–1995	1.16	7.74	0.15	− 43	30	9.43
Indonesia						
1987–1997	1.89	11.94	0.16	− 28	67	7.95
Israel						
1987–1997	0.14	4.79	0.03	− 16	13	6.05
Jordan						
1987–1997	0.17	4.79	0.04	− 20	11	6.47
Korea						
1987–1997	0.25	8.33	0.03	− 28	23	6.12
Malaysia						
1987–1997	1.36	6.71	0.20	− 17	19	5.37
Mexico						
1987–1997	2.23	10.30	0.22	− 41	25	6.41
Philippines						
1987–1997	1.43	8.45	0.17	− 26	31	6.75
Singapore						
1986–1995	0.98	6.89	0.14	− 41	17	8.41
Taiwan						
1986–1995	2.01	15.51	0.12	− 61	71	8.45
Thailand						
1987–1997	2.04	9.08	0.22	− 29	46	8.26
Turkey						
1987–1997	1.05	17.04	0.06	− 40	55	5.59

Notes: Monthly return is computed as $R_t = \ln(P_t/P_{t-1})^* 100$, where P is the stock price index (adjusted for dividend) at the last trading day of each month. Standardized return is average mean return of each series divided by the series' standard deviation (i.e., an approximate Sharpe ratio). The Studentized range, which indicates non-normality of return distribution if it is at or above 6.0, is computed as $(\mathrm{Max}[R]-\mathrm{Min}[R])/\sigma_R$.

Single variance ratio test results

The results of variance ratio tests are presented in Tables 2a and 2b. Given that we used observation intervals $q = 2, 4, 8, 16$ months, with a base of one month, variance ratio estimates are computed for two-month, four-month, eight-month and sixteen-month observation intervals. As shown in Tables 2a and 2b, the estimates of the variance ratios are in the main rows and the asymptotic Z and Z^* statistics under homoskedasticity and heteroskedasticity are reported in parentheses and brackets, respectively. For the moment, our discussion will focus on Table 2a, which reports on results of US dollar-based data. The Z-statistics indicate that a US investor's equity returns in Argentina, Hong Kong,

Table 1b. Descriptive statistics of local currency based monthly equity returns of fifteen emerging markets

Country Period	Mean Return	Standard Deviation	Standardized Return	Min (R)	Max [R]	Studentized Range
Argentina						
1987–1997	10.69	29.80	0.36	– 52	132	6.17
Brazil						
1987–1997	11.81	73.84	0.16	– 233	223	6.18
Chile						
1987–1997	3.42	6.94	0.49	– 15	20	5.07
Hong Kong						
1986–1995	1.69	10.09	0.16	– 45	36	8.03
Indonesia						
1987–1997	2.27	12.64	0.18	– 28	67	7.52
Israel						
1987–1997	4.80	46.50	0.10	– 16	454	10.11
Jordan						
1987–1997	0.99	4.61	0.21	– 12	13	5.43
Korea						
1987–1997	0.68	7.84	0.09	– 22	23	5.74
Malaysia						
1987–1997	1.49	7.02	0.21	– 17	24	5.86
Mexico						
1987–1997	3.74	9.50	0.39	– 23	28	5.37
Philippines						
1987–1997	2.01	8.94	0.23	– 30	26	6.29
Singapore						
1986–1995	0.91	7.14	0.13	– 39	19	8.12
Taiwan						
1986–1995	1.55	15.13	0.10	– 49	41	5.95
Thailand						
1987–1997	2.11	8.68	0.24	– 18	31	5.65
Turkey						
1987–1997	4.84	16.22	0.30	– 29	56	5.24

Notes: Monthly return is computed as $R_t = \ln(P_t/P_{t-1})^* 100$, where P is the stock price index (adjusted for dividend) at the last trading day of each month. Standardized return is average mean return of each series divided by the series' standard deviation (i.e., an approximate Sharpe ratio). The Studentized range, which indicates non-normality of return distribution if it is at or above 6.0, is computed as $(\mathrm{Max}[R]{-}\mathrm{Min}[R])/\sigma_{\mathrm{R}}$.

Israel, Korea, Malaysia, and Singapore follow a random walk, while investor's stock return series in Brazil, Chile, Jordan, Indonesia, Mexico, the Philippines, Taiwan, Thailand and Turkey do not follow random walks, according to the LOMAC test. For these latter nine series, the estimated variance ratios are statistically different from 1.0 at the 5% significance level when the Z-statistics are compared with the 1.64 critical value of the standard normal distribution. Four of the fifteen series we analyzed are from Latin America, and among them Brazil, Chile and Mexico series do not follow random walk under the LOMAC test, whereas Argentina does. This result agrees with Urrutia (1995) for three of the four Latin American series examined by both studies. Urrutia used LOMAC's variance ratio tests and local currency-based data to test the RWH for the four series and

Table 2a. Results of CHODE & LOMAC tests for emerging equity markets, with US dollar based data: estimates of variance ratios, $VR(q)$, the statistics $Z(q)$ and Z^* (q) are reported for alternative aggregation intervals $q = 2, 4, 8$, and 16 months.

		Number q of base observations aggregated to form Vr(q)			
Country/Stocks:	Monthly Series	2	4	8	16
Argentina	114	1.059	1.002	0.929	0.874
1987:12–1997:5		(0.63)	(0.02)	(− 0.27)	(− 0.41)
		[0.22]	[0.05]	[− 0.28]	[− 0.16]
Brazil	114	0.844	0.711	0.507	0.483
1987:12–1997:5		(− 1.59)	(− 1.61)	(− 1.64)*x*	(− 1.16)
		[− 0.49]	[− 0.63]	[− 0.79]	[− 0.59]
Chile	114	1.299	1.386	1.335	1.702
1987:12–1997:5		(3.19)*	(2.20)*x*	(1.42)	(1.70)x
		[1.37]	[1.17]	[0.64]	[0.70]
Hong Kong	120	1.014	0.915	0.677	0.449
1986:1–1995:4		(0.15)	(− 0.49)	(− 1.19)	(− 1.35)
		[0.04]	[− 0.15]	[− 0.43]	[− 0.60]
Indonesia	114	1.119	1.236	1.360	1.951
1987:12–1997:5		(1.26)	(1.34)	(1.30)	(2.30)x
		[0.30]	[0.44]	[0.40]	[0.73]
Israel	114	1.082	1.147	1.039	1.102
1987:12–1997:5		(0.52)	(0.49)	(0.08)	(0.14)
		[0.24]	[0.49]	[0.05]	[0.07]
Jordan	114	1.061	1.114	1.338	1.948
1987:12–1997:5		(0.64)	(1.65)*x*	(1.22)	(2.29)x
		[0.28]	[0.36]	[0.66]	[1.03]
Korea	114	0.943	0.943	1.084	1.201
1987:12–1997:5		(− 0.45)	(− 0.33)	(0.30)	(0.48)
		[− 0.20]	[− 0.18]	[0.16]	[0.23]
Malaysia	114	0.920	0.945	0.645	0.758
1987:12–1997:5		(− 0.85)	(− 0.31)	(− 1.28)	(− 0.58)
		[− 0.41]	[− 0.18]	[− 0.73]	[− 0.28]
Mexico	114	1.254	1.396	1.435	2.067
1987:12–1997:5		(2.54)*	(2.25)*x*	(1.57)	(2.33)x
		[0.70]	[0.79]	[0.56]	[0.70]
Philippines	114	1.200	1.500	1.710	1.661
1987:12–1997:5		(2.13)*x*	(2.85)*	(2.53)*	(1.78)x
		[0.83]	[1.39]	[1.07]	[0.65]
Singapore	120	1.279	1.158	1.009	0.730
1986:1–1995:4		(1.40)	(0.92)	(0.33)	(− 0.65)
		[0.26]	[0.23]	[0.01]	[− 0.25]
Taiwan	120	0.594	0.370	0.258	0.194
1986:1–1995:4		(− 4.44)*	(− 3.68)*	(− 2.75)*	(− 1.98)*x*
		[− 1.24]	[− 2.11]*x*	[− 1.13]	[− 0.86]
Thailand	114	1.235	1.403	0.871	0.969
1987:12–1997:5		(2.35)*x*	(2.24)*x*	(− 0.44)	(− 0.21)
		[0.78]	[0.87]	[− 0.18]	[− 0.09]
Turkey	114	1.239	1.405	1.603	1.600
1987:12–1997:5		(2.55)*	(2.30)*x*	(2.17)*x*	(1.46)
		[1.03]	[1.18]	[1.02]	[0.59]

found they did not follow a random walk. However, this result changes when we applied CHODE's variant of the variance ratio test—which is a major thrust of our study. For example, among the Latin American series, Argentina and Brazil are found to follow a random walk under CHODE's test. This is discussed further in the next few sections.

Multiple variance ratio test results

To both examine variance ratios in a multiple statistical comparison and control the size of the multiple test, CHODE's methodology compares LOMAC's test statistics with the studentized maximum modulus (SMM) distribution critical value of 2.491. his critical value corresponds to a 5% level of significance for the variance ratios (e.g., for the four aggregation intervals $q = 2, 4, 8, 16$) estimated for each of the fifteen series.

For clarity of the text, we used two symbols to identify statistical significance. In Tables 2a and 2b, the symbol ''*'' indicates that the variance ratio is statistically different from 1.0 at the 5% level under CHODE's variant of the variance ratio test. The symbol ''*x*'' identifies an inferential error, where a variance ratio is significantly different from 1.0 when a corresponding statistic is compared to the critical value of the standard normal distribution, but in fact, it is insignificantly different from 1.0 when the statistic is compared with the SMM critical values in a joint-test. For example, when one uses the critical value of 1.64 for the 5% significance level on the standard normal distribution (in Table 2a), there is evidence that equity returns in Thailand and Brazil do not follow random walks. However, with the SMM distribution critical value of 2.491, the RWH for the Thai and Brazilian stock series is supported. Thus, the use of CHODE's test technique most clearly highlights inferential errors that may arise from using LOMAC's single-tests alone and ignoring the joint nature of the variance ratio approach to testing the RWH. To further appreciate the importance of properly specifying the test for RWH, one only needs to look at Table 2a, where erroneous inferences would have been drawn in 14 of the 60 variance ratios estimated (i.e., erroneous *Z*-statistics are marked *x*).

Furthermore, a comparison of the $Z(q)$ and $Z^*[q]$ statistics suggests the test results under homoskedasticity are robust to heteroskedasticity. When heteroskedastic-consistent statistics are considered, five of the series (Chile, Indonesia, Jordan, Mexico, and Turkey) which originally were not consistent with the RWH become consistent with it. In this respect, our findings agree with those documented by Chow, Pan, and Sakano (1996). Chow et al. examined the dynamics of 22 international stock indices and found that most of them follow random walks. Their finding contrasts those of Fama and French (1988), and Porteba and Summers (1988), which suggest that international equity returns exhibit

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Notes: In Table 2a, the estimates of the variance ratios are reported in the main rows. The homoskedasticity and heteroskedasticity robust *Z*-statistics are reported in parenthesis (–) and brackets [–], respectively. The symbol ''*'' indicates that the variance ratio is statistically different from unity at the 5% significance level when compared with the SMM critical value of 2.491. The symbol ''*x*'' indicates an inferential error in which the variance ratio is statistically different from 1.0 according to the standard normal distribution critical value, but is insignificant under the SMM distribution critical value.

Table 2b. Results of CHODE & LOMAC Tests for Emerging Equity Markets, with Local Currency Based Data: Estimates of Variance Ratios, $VR(q)$, the statistics $Z(q)$ and $Z^*(q)$ are reported for alternative aggregation intervals $q = 2, 4, 8$, and 16 months

		Number q of base observations aggregated to form Vr(q)			
Country/Stocks:	Monthly Series	2	4	8	16
Argentina	114	1.167	1.732	2.383	3.966
1987:12–1997:5		(1.65)x	(3.85)*	(1.61)	(1.67)x
		[0.39]	[1.05]	[1.14]	[1.38]
Brazil	114	0.567	0.350	0.345	0.432
1987:12–1997:5		(− 4.24)*	(− 3.42)*	(− 2.19)x	(− 4.46)*
		[− 2.63]*	[− 2.76]*	[− 2.09]x	[− 1.12]
Chile	114	1.318	1.478	1.377	1.157
1987:12–1997:5		(3.14)*	(2.52)*	(1.25)	(0.35)
		[1.38]	[1.33]	[0.60]	[0.47]
Hong Kong	120	0.648	0.376	0.241	0.190
1986:1–1995:4		(− 3.59)*	(− 3.40)*	(− 2.61)*	(− 2.02)x
		[− 1.92]x	[− 2.50]x	[− 2.16]x	[− 1.72]x
Indonesia	114	1.120	1.262	1.448	2.133
1987:12–1997:5		(1.18)	(1.38)	(1.49)	(2.35)x
		[0.27]	[0.41]	[0.47]	[0.70]
Israel	114	1.096	1.210	1.142	1.188
1987:12–1997:5		(0.95)	(0.42)	(0.47)	(0.43)
		[0.27]	[0.74]	[0.16]	[0.13]
Jordan	114	1.125	1.190	1.233	1.509
1987:12–1997:5		(1.23)	(1.00)	(0.77)	(1.16)
		[0.51]	[0.54]	[0.39]	[0.48]
Korea	114	0.918	0.837	0.847	0.977
1987:12–1997:5		(− 0.97)	(− 1.90)x	(− 0.50)	(− 0.59)
		[− 0.49]	[− 0.54]	[− 0.33]	[− 0.23]
Malaysia	114	0.878	0.960	0.780	0.982
1987:12–1997:5		(− 1.20)	(− 0.20)	(− 0.26)	(− 0.59)
		[− 0.55]	[− 0.41]	[− 0.37]	[− 0.28]
Mexico	114	1.092	1.050	1.007	1.365
1987:12–1997:5		(0.89)	(0.26)	(0.22)	(0.81)
		[0.37]	[0.12]	[0.12]	[0.35]
Philippines	114	1.235	1.415	0.899	0.914
1987:12–1997:5		(2.31)x	(2.18)x	(1.07)	(0.65)
		[0.79]	[0.88]	[0.34]	[0.19]
Singapore	120	0.570	0.364	0.281	0.165
1986:1–1995:4		(− 4.36)*	(− 3.46)*	(− 2.47)x	(− 1.94)x
		[− 3.01]*	[− 2..98]*	[− 2.27]x	[− 1.74]x
Taiwan	120	1.093	1.143	1.238	1.449
1986:1–1995:4		(1.12)	(0.92)	(0.96)	(1.22)
		[0.40]	[0.38]	[0.38]	[0.41]
Thailand	114	1.150	1.396	1.523	1.282
1987:12–1997:5		(1.48)	(2.08)x	(1.86)x	(0.91)
		[0.64]	[1.05]	[0.79]	[0.24]
Turkey	114	1.150	1.255	1.528	1.670
1987:12–1997:5		(1.48)	(1.34)	(1.76)x	(1.50)
		[0.64]	[0.74]	[0.82]	[0.53]

dependency. In fact, in few of the cases where Chow et al. found non-random walk dynamics, the rejections of the RWH were weak. The upshot of this result is that, viewed from a US investor's perspective, most emerging markets' equity returns seem to follow random walk under a properly specified RWH test. Results of 10 of the 15 emerging markets we studied are consistent with the RWH under CHODE's test specification, while only 5 of the 15 would have been consistent with the RWH under LOMAC's test.

Variance ratio results from local investors' perspective

To examine the presence of exchange rate effects on test of financial asset's dynamics, we took a local (domestic) investor's perspective and compared the resulting outcome with that documented when exchange rate-adjusted data was used (as shown in Table 2a). In other words, we used local currency-based data to examine both LOMAC's and CHODE's tests results. As can be seen in Table 2b, a domestic investor would perceive 10 (namely, Indonesia, Israel, Jordan, Korea, Malaysia, Mexico, Philippines, Taiwan, Thailand, and Turkey) of the 15 equity return series to follow random walk under CHODE's test. Conversely, 6 (namely, Israel, Jordan, Korea, Malaysia, Mexico and Taiwan) out of 15 would follow random walk under LOMAC's test. As was the case in Table 2a, the result in Table 2b becomes more consistent with the RWH when adjusted for heteroskedasticity than without such an adjustment.

Upon casual observation, this set of results (i.e., Table 2b) may seem similar to that in Table 2a, which is based on exchange rate-adjusted data. A closer comparison of results in the two Tables, 2a and 2b, reveal an interesting pattern. Results on Argentina, Brazil, Hong Kong, Indonesia, Mexico, Philippines, Singapore, Taiwan, and Turkey equity returns are not consistent under the two disparate investors' perspectives: international (US investors') and domestic investors'. Interestingly, the countries from which these series emanate have had marked unsettled exchange rate regime history (with the exception of Hong Kong), as is evident in the *World Currency Yearbook* series (for the 1980–1997 period). Where that is not the case, as in Singapore and Taiwan, the countries are known to have had stringent monetary and exchange rate controls (Loong (1987) and Chen and Hsiao (1997)). Therefore, the result differences between Tables 2a and 2b suggest that the exchange rate matters in the determination of emerging market equity returns' dynamics. This, in turn, largely influences what investment strategy an international investor would employ when investing in emerging market equities (or other financial assets).

Notes: In Table 2b, the estimates of the variance ratios are reported in the main rows. The homoskedasticity and heteroskedasticity robust *Z*-statistics are reported in parenthesis (–) and brackets [–], respectively. The symbol "*" indicates that the variance ratio is statistically different from unity at the 5% significance level when compared with the SMM critical value of 2.491. The symbol "*x*" indicates an inferential error in which the variance ratio is statistically different from 1.0 according to the standard normal distribution critical value, but is insignificant under the SMM distribution critical value.

Tests of market efficiency

The variance ratio analysis of the random walk processes of the 15 emerging equity markets suggests some potential alternative interpretation for the absence of random walks. For instance, a variance ratio estimate greater than 1.0 suggests that the RWH is not supported due to the presence of positive serial correlation in the stock return series. An estimate that is significantly less than 1.0 indicates nonsupport for the RWH due to negative serial correlation. However, given that the absence of random walks does not necessarily preclude the efficiency of markets, as Lucas (1978) and Summers (1986) suggested, a direct test for market efficiency was conducted. Among other reasons, such a test is important because foreign investors would want to know that they are not automatically rendered noise traders[5] by informational disadvantage when they invest in emerging markets. Furthermore, this test is important because of the growing interest in emerging market investments, and because some glaring government interventions (e.g., exchange rate controls, dividend and/or capital repatriation restrictions, and ownership restrictions) still exist in some of these markets (For example, see Errunza (1983), Errunza and Losq (1985), and Gooptu (1993)).

The popular nonparametric runs test, which tests for independence between successive events (in a series) without requiring normality of distribution, is used to test for the weak-form efficiency of the selected fifteen emerging markets. The runs test is appropriate for our study because Errunza and Losq (1985), Claessens, Dasgupta and Glen (1993), Urrutia (1995) and our Table 1, provide evidence against normality for emerging markets' equity returns distribution. We perform the runs test on both the US dollar-based data and local currency-based data to provide further insights into the variance ratio results; especially for markets which are weak-form efficient, but whose equity series do not follow random walks. Column 3 in Table 3 reports the Z-statistics reflecting the status of weak-form market efficiency for each market, when efficiency is viewed from a US investor's perspective. Column 4 in Table 3 reports the same when viewed from a local investor's perspective.

According to the Runs test statistics in column 3 of Table 3, the hypothesis of independence cannot be rejected at the 5 percent level for 9 of the 15 equity return series. Evidence suggests Chile, Israel, the Philippines, Singapore, Taiwan and Thailand markets are not weak-form efficient when these markets are explored from an international investor's perspective. Here our finding essentially agrees with that of Urrutia (1995), who found all four Latin American markets to be weak-form efficient. We found three of the same four Latin American markets Urrutia studied to be weak-form efficient. Only Chile yielded a contrary result. However, when we use local currency-based data, as Urrutia did, two (Argentina and Chile) of the Latin American markets become weak-form inefficient. Differences in study periods may explain this contrast in market efficiency result between our study (using the period 1986–1996) and Urrutia's (with the period 1975–1991).

As can be seen in column 4 of Table 3, 12 of the 15 emerging equity markets are weak-form efficient from the perspective of local investors. Only Argentina, Chile, and Singapore appear not to be weak-form efficient. Relative to the result in column 3, this result is expected because local investors can have slight information advantage over international investors, especially in an emerging market with nascent infrastructure. As

Table 3. Market efficiency test results: runs tests of 15 emerging equity markets with monthly equity returns series expressed in both US dollar and local (domestic) currency

Country	Observations	*Z* [US $]	*Z* [LC]
Argentina 1987:12–1995:12	114	– 0.22	– 2.58*
Brazil 1987:12–1995:12	114	0.15	1.17
Chile 1987:12–1995:12	114	– 2.66*	– 3.67*
Hong Kong 1986:1–1995:4	120	– 0.24	1.29
Indonesia 1987:12–1995:12	114	– 0.62	– 1.31
Israel 1987:12–1995:12	114	– 4.40*	0.15
Jordan 1987:12–1995:12	114	0.14	– 0.89
Korea 1987:12–1995:12	114	– 0.72	– 0.14
Malaysia 1987:12–1995:12	112	0.66	1.60
Mexico 1987:12–1995:12	114	– 0.85	– 1.61
Philippines 1987:12–1995:12	114	– 3.29*	– 1.20
Singapore 1986:1–1995:4	120	– 1.93*	– 2.67*
Taiwan 1986:1–1995:4	120	– 3.06*	– 1.48
Thailand 1987:12–1995:12	114	– 2.26	– 1.43
Turkey 1987:12–1995:12	114	– 0.18	0.16

Notes: *Z*[US $] indicates whether or not a country's market is weak-form efficient when viewed from international investors' perspective, and *Z*[LC] indicates the same when viewed from local investors' perspective. * indicates significance at the 5% level. All statistics are computed according to the SPSS program specifications.

mentioned earlier, these efficiency tests are more important, economically, when viewed in the context of the tests for each market's asset dynamics. These two tests' (variance ratio and runs tests) results viewed in conjunction with each other, provide either local or international investors with information for a better investment strategy than when each test's outcome is viewed in isolation of each other. This insight is explored further in the next section

Economic implications of the results

Our test results suggest that a large number of the emerging markets analyzed exhibit random walk, whether viewed from a local or an international investor's perspective. Such dynamics behavior implies that current returns may be predicted based only on most recent return series (i.e., these return series are not serially correlated). Therefore, random walk properties-guided trading strategies can be useful in these emerging equity markets (as implied in Fama (1970), Poterba and Summers (1988), and Eckbo and Liu (1993)) in their various studies of financial assets' dynamics). However, a few of the emerging markets' equities appear not to follow random walks. The rejection of random walk does not necessarily imply inefficiency in a market. Therefore, to ensure a better interpretation of the RWH rejection, a runs test for market efficiency was conducted for each of the fifteen markets. The result suggests most of the analyzed markets are weak-form efficient. Hence, there is a need to explain the presence of positive and/or negative serial correlation when a market is, at the same time, documented to be weak-form efficient.[6]

Specifically, from an international investor's perspective, equity returns of Chile, Mexico, the Philippines, and Turkey exhibit positive autocorrelation. Of these four markets, the market efficiency test supports rejections of the RWH for the equity returns of Chile and the Philippines. Thus, the Mexico and Turkey returns' inconsistency with the RWH requires explanation. Similarly, from the local investor's perspective, Argentina and Indonesia equity returns exhibit positive serial correlation, with Indonesia's returns dynamics needing further explanation. Lo and MacKinlay (1988, pp. 56–60) and Poterba and Summers (1988, pp. 45–48) explain in some detail how infrequent or nonsynchronous trading patterns can yield a positively autocorrelated stock price series behavior. A plausible justification for this deduction comes from Lo and MacKinlay, who posit that small-capitalized firms trade less frequently than large-capitalized firms. Therefore information is impounded first into large-capitalized firms' prices, and then small-capitalized firms', with a lag; and this lag induces a positive serial correlation in the index series that contain these distinct capitalized groups of stocks. Given the market concentration of top large companies whose stocks dominate the emerging market indices (as reflected in Claessens, Dasgupta and Glen, (1993, Table 1)), this explanation is not far-fetched. Another plausible reason for positive autocorrelation in emerging equity markets' series is the effects of government interventions (e.g., see Liu and He (1991) and Gooptu (1993)).

Interestingly, only Taiwan equity returns, from international investors' perspective, and Brazil, Hong Kong, and Singapore, equity returns from local investors' perspective, exhibit negative serial correlation[7]. These suggest the presence of mean-reversion (which is amply expounded by Summers (1986), Fama and French (1988), and Poterba and Summers (1988, pp. 45–61)). In a nutshell, this means if stock price returns do revert to means, they should be negatively serial correlated, and the variance ratio should get smaller and smaller than unity as the interval q increases. Poterba and Summers (1988) posit that the stationary transitory component of equity return series that exhibit mean-reversion is, perhaps, best explained by the influence of noise traders (those trading on the basis of fad or just speculation) in the market. Thus, a tendency for people to dabble in stock trade for status symbol, or people's mere penchant for speculating in emerging markets, if dominant, can explain the negative serial correlation in their equity series, especially in that of Taiwan and Singapore. (Loong (1987) and Chen and Hsiao (1997) provide some anecdotal evidence in support of the preceding conjecture).

Conclusions

Theory holds distinct implications for investment strategies designed to exploit security returns, depending on whether or not the returns are random walk processes. To ascertain the nature of such implications for emerging markets' equity investment, our paper adopted the multiple variance ratio technique of Chow and Denning (1993) to test the RWH for equity returns in 15 emerging markets. CHODE's method tests jointly the unity of variance ratio estimates and controls the joint-test size. Furthermore, CHODE's method uses the studentized maximum modulus distribution to control the joint-test size and, thus, achieve a lower probability of type-1 error. Lo and MacKinlay (1988) single variance ratio test ignores the joint-test nature of the variance ratio approach to random walks and thus can lead to erroneous inferences. Consequently, CHODE's method implies that inferences based on LOMAC statistics (which have been extensively used in RWH tests) should be interpreted with caution. We find that the majority of the emerging equity series analyzed here are both consistent with the RWH and weak-form efficient when both local currency-based data and exchange rate-adjusted data are used.

Additionally, we document that exchange rates matter in the determination of emerging markets' equity returns' dynamics. Investing in countries that have a history of marked exchange rate regime instability, yielded different equity return dynamics for international and local investors. Most noted of such countries, in our study, are Argentina, Brazil and Mexico in Latin America; and Philippines, Indonesia, Taiwan and Singapore in Southeast Asia.

The general thrust of our empirical results, therefore, is that using properly specified multiple variance ratio method (such as CHODE's (1993)) instead of single variance ratio methods to study equity returns' dynamics, suggests the majority of analyzed emerging markets are consistent with the RWH. The results reveal that most analyzed markets are weak-form efficient. The findings suggest that investors are unlikely to make systematic nonzero profit by using past information in many of the markets, but Investors may be able to predict equity returns using random walk properties for the majority of the emerging equity markets examined. In this respect, our findings agree with findings by Claessens et al. (1993) and Chow et al. (1996), and contrast results of similar studies that have been documented for industrial equity markets (e.g., Fama and French (1988), Lo and MacKinlay (1988), and Porteba and Summer (1988)).

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Notes

1. Mean-reversion is considered more or less an alternative to the random walk hypothesis of the stochastic behavior of asset (stock) price series. Mean-reversion specification holds that stock price movement is the sum of a random walk and a stationary mean-reverting process. For further details on this topic, see Poterba and Summers (1988).
2. The random walk hypothesis is defined in some detail in both equations (1) and (6) of this paper.
3. The International Finance Corporation (IFC) is a private sector arm of the World Bank, which focuses primarily on member countries' investment analysis and advising. Consequently, it compiles and provides one of the most extensive and up-to-date financial information on emerging capital markets (e.g., national stock indices).
4. The Sharpe-ratio computed in this study provides a measure of the return-risk profiles of the emerging equity markets examined here. Unlike the standard Sharpe-ratio, computed as an asset's excess return divided by the asset's standard deviation, the approximate Sharpe-ratio is computed as each series' mean return divided by the series' standard deviation.
5. A noise trader is an investor whose security trading decisions are based on other justifications rather than on his economic analysis of what expected values of securities should be.
6. We concentrate here on explaining equity dynamics that are inconsistent with random walks as a means of ascertaining the extent of efficiency in the markets analyzed. Explaining why a market may not be weak-form efficient is beyond the scope of the present study. Readers interested in such a study should see Errunza and Losq (1985), Claessens et al. (1993), Gooptu (1993), and Karemera and Ojah (1996).
7. Lo and MacKinlay (1988), Poterba and Summers (1988), and Liu and He (1991) explain that variance ratios significantly greater than 1.0 suggest presence of positive serial correlation. Then, the RWH is rejected due to positive autocorrelation in the series. Variance ratios significantly less than 1.0 suggest existence of negative serial correlation and the RWH and rejection of the RWH due to negative autocorrelation.

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