INTERNATIONAL JOURNAL OF BUSINESS, 9(1), 2004 ISSN:1083-4346

Memory in World Stock Prices

Bala G. Arshanapalli[a]
Larry Belcher[b]
Christopher K. Ma[c]
James E. Mallett[d]

[a] *Indiana University Northwest, bala@iunbus1.iun.edu*
[b] *Department of Finance, Stetson University, lbelcher@stetson.edu*
[c] *Department of Finance, Stetson University, kcma95@aol.com*
[d] *Department of Finance, Stetson University, jmallett@stetson.edu*

ABSTRACT

The random walk hypothesis is rejected for foreign stock market prices. Variance ratio tests are performed on weekly stock prices of nine major foreign stock market indices. While longer-term returns follow random walks, short-horizon, bi-weekly returns exhibit significant positive serial correlation.

JEL: *C0, C4, D4, F3*

Keywords: *Random walks; Memory; International stock prices; Variance ratio; Mean reverting*

I. INTRODUCTION

In recent years, much controversy has been raised regarding the time series properties of the stock returns. It has been shown that the long-horizon stock returns using monthly and annual data exhibit negative serial correlations (Fama and French, 1988; Lehmann, 1989; Paterba and Summers, 1988; Cecchetti, Lam and Mark, 1989). The common evidence suggests that there are information components in past prices that can be used to predict future prices; price movements in stock markets violate the random walk hypothesis. While such a conclusion may contradict the findings in earlier studies (Working, 1934; Kendall, 1953; Roberts, 1959; Alexander, 1961), further complications surface when nonuniform evidence is found in returns of different time horizons. For example, both French and Roll (1986) and Lo and MacKinlay (1988) show that daily and weekly *individual* security returns are negatively autocorrelated, but Conrad and Kaul (1988), Lo and MacKinlay (1988) find that weekly *portfolio* returns demonstrate positive serial correlation.

In an effort to explain return dependence, Conrad, Kaul and Nimalendran (1989) decompose the daily stock return series into positively autocorrelated expected return component, a negatively autocorrelated bid-asking spread component, and an independent random component. Ma (1990) presents similar findings in the daily GNMA bond prices, but concludes that the unexpected information component is positively autocorrelated. These studies provide the empirical justification for the need to distinguish the relationship between individual components in the price series.

To test the robustness of the results and avoid the "data snooping" problem often found in the U.S. time series, this study investigates the random walk hypothesis in nine major foreign stock market indices. Three components are identified in the price series: a systematic component reflecting the expected information, a negatively autocorrelated component which is attributed to the bid-asking spread of the marketmaker's behavior, and a noise term which represents the pricing on the unexpected information. The evidence suggests that the short-horizon (ie. 2-week holding period) realized return exhibits persistence. The sources of the time dependence cannot be explained by the bid-asking spread, the underlying nonnormality of the return distribution, or the systematic movement of the underlying structure. Therefore the implication is that the foreign stock prices did not react to unexpected information in a rational fashion, and the adjustment process is not instantaneous. However, once the holding period is extended to a month, the null hypothesis of random walk cannot be rejected.

II. THE MODEL

Before we investigate the nature of random walks, it is important to make the distinction between anticipatory and random elements in a price series (see Working, (1934)). Furthermore Houthakker (1934) pointed out that randomness of a process could be defined only in the absence of any systematic pattern. Conrad, Kaul and Nimalendran (1991) have shown that the stock return series exhibit different time-series properties and therefore the distinction between the anticipatory and the random components are very important. Furthermore, Conrad and et al (1991) have shown that short-horizon realized returns exhibit negative dependence. However, they showed that negative dependence is most due to the bid-asking spread rather than due to the randomness. Thus, some have argued that the systematic structure of the time series, if expected, should be deterministic.

Consequently, the testing of the random walk hypothesis should be only relevant with respect to the random component of the price series. To properly show the impact on the variance from various components in the return series; the price formation process should be described as follows. At time t =1, the i^{th} investor forms expectations of price at time t based on the information available at t-1, X_{t-1}, and can be written as

$$E(P_t / \phi_{t-1}) = \alpha + \beta X_{t-1} \quad (1)$$

where α & β are parameters and X_{t-1} is the information available in time period $_{t-1.}$ Further, it is also assumed that investors enter at time t-1 with probability beliefs prob (.) defined over the information set ϕ_t. The information available in time period t-1 (X_{t-1}) is a subset of ϕ_t. The actual formation process can be described as

$$P_t = E_{t-1}(Pt/ \phi_{t-1}) + e_t + b(X_t - X_{t-1}) \quad (2)$$

where e_t is assumed to be identically and independently distributed (iid), X_t is the information available at time t. The difference (X_t-X_{t-1}) is the incremental information set available from t-1. Thus, the actual price is a fraction of expected price component at t-1, systematic component (X_t – X_{t-1}) which may be attributed to risk premium or bid-ask spread or trend specific to certain specific periods, and a random component. The testing of random walk hypothesis involves the testing of the time-series properties of the noise terms, e_t. Since stock prices are non-stationary, returns are used in our empirical model.

To separate the random component from the systematic component reflecting the changes of an underlying economic model, we employ the variance ratio test first developed by Tintner (1940) and the corresponding tests statistics by Lo and MacKinlay (1988). Specifically, let P_t represent the asset price at time t and L_t be the natural logarithm of prices. The continuously compound return, R_t which is the difference in successive log-prices, should contain three components: a systematic component, ϕ_t, which is differentiable with respect to time and determined by the underlying fundamentals of the asset; bid-ask spread component, δ_t S, reflecting the impact of dealer's marketmaking behavior; and a random innovation, ε_t generated by unexpected random causes. Therefore,

$$\mathrm{Log}(P_t/P_{t-1}) = \phi_t + (\delta_t - \delta_{t-1})S + \varepsilon_t, \quad (3)$$

where cov(ϕ_t, ε_t)=0, cov(δ_t,ε_t)=0, cov (ϕ_t, δ_t)=0, E(ε_t)=E(δ_t)=0, and cov (δ_t, δ_{t-1})=ρ_1 < 0.

In equation (3), S is the level of a time-invariant bid-ask spread, and δ_t is the stochastic variable for the transaction type of the price, Pt: $\delta_t = 1$ if the transaction price is an ask price and $\delta_t = -1$ for a bid price.

In addition, bid-ask spread is introduced in equation (3) to account for non-trading effects. The studies that use monthly or annual data (see for example, Fama and French, 1988 or Paterba and Summers 1999) are less likely to be affected by non-trading at those frequencies. However, in daily or weekly studies, it has been shown that returns show positive correlation due to infrequent trading, (see Conrad, Kaul and Numalendran, 1991). For example, if some of the securities in the market index trade infrequently, these securities will have higher bid-ask spread to reflect the illiquidity of these securities. Furthermore, we are using index data of 9 countries, the inclusion of bid-ask spread in equation 3 became even more important to account for non-trading effects. It makes even more sense to include bid-ask spread especially to account for different market microstructures of these countries.

As market makers stand ready to offer a (higher) price to sell and ask a (lower) price to buy, the differences between the two prices, in the form of positive bid-ask spreads, is the reward for market makers for providing the liquidity services. Roll (1984) argues that if buy and sell orders arrive randomly in a non- trending market, market prices will tend to vary between the bid and ask prices in such a way that the observed prices changes act as if they are negatively autocorrelated. Thus, the correlation between the successive transaction types, ρ_1, is assumed to be negative. A mean of zero for δ_t reflects the assumption that there is no concentration on the type of the transaction for the entire sample period. By definition, ϕ_t, δ_t, and ε_t are independent. The components of the spread variables in equation (1) reflect the effect of the transaction type of the quoted prices on the computed returns. When two successive prices are the same type of transaction, i.e., $\delta_t = \delta_{t-1}$, there is no measurement bias of bid-ask spreads in the returns or the variances. Conversely, if the bid and ask prices reverse perfectly from price to price; there is a significant bias in the return variances.

In order to test empirically equation (3), it is important to neutralize the impact of systematic component. It should be noted, however, that the systematic component can be serially correlated due to the nature of the economic determinants which may be time- path dependent. That is, cov (ϕ_t, ϕ_{t-1}) is not necessarily equal to zero. Based on the specification in equation (1), ε_t, are said to follow a Gaussian *random walk,* if and only if, the noise component is independent of time and normally distributed with an expected value of zero and variance equal to σ^2. It is necessary, therefore, to isolate the noise component from the entire series, which can be accomplished by taking finite differences of the price series. When a lag, q, is used to finite differences the series, any systematic pattern of ϕ_t that exists between P_t and, P_{t-q} should be irrelevant in determining the variance ratios. Thus, the finite differencing of a series will eliminate or at least reduce to any desired degree on the importance of the systematic component without changing the random component (Powers, 1971). On the other hand, the random component cannot be reduced by finite differencing since it is not ordered in time.

The above tests is often considered superior to traditional white-noise tests or autocorrelation tests for random walks, since it does not require that the underlying *ex ante* economic model be specified. The traditional autocorrelation method assumes either that there is no systematic component in the underlying process (martingale) or that the economic model be specific ad hoc in order to distinguish the random component ε_t for testing. In either case, the hypothesis is always a joint test for both the validity of the model and the independence of the ε_t. Therefore, there should exist a non- negative integer, q, which will eliminate the impact of the systematic structure, and equation (3) can be written as:

$$\text{Log}\ (P_t/P_{t-q}) = \sum_{k=0}^{q} \varepsilon_{t-k} + (\delta_t - \delta_{t-q})S$$

and the variance of the q- period return is:

$$V(R_q) = \sum_{k=0}^{q} V(\varepsilon_{t-k}) + 2S^2 V(\delta_t) + \sum_{i=0}^{q}\sum_{j=0}^{q} \text{Cov}(\varepsilon_{t-i}, \varepsilon_{t-j}) - 2S^2 \text{Cov}(\delta_t, \delta_{t-q})\text{, where } i \neq j.$$

The random walk hypothesis would require that ε_t be independent and identically distributed (i. i.d.). Therefore, let $\sigma_\delta^2 = V(\delta_t)$, and $\rho_q = \text{Cov}(\delta_t, \delta_{t-q})$,

$$V(R_q) = qV(\varepsilon_t) + 2\ S^2(\sigma_\delta^2, \rho_q) \tag{4}$$

Assume that bid-ask spread does not exists, equation (4) is reduced to $V(R_q) = qV(\varepsilon_t) = q\sigma^2$. Thus, the familiar unit- root variance ratio and the following necessary condition for random walks must hold:

$$\lambda(q) = V(q)/[V(1)q] = 1, \tag{5}$$

where $\lambda(q)$ represents the variance ratio of the finite difference log-price series. The variance ratio test compares the variance of a q-period return to that of the product of q and the variance of a one-period return. To test the null hypothesis that the time-variance relationship in equation (5) holds, finding $\lambda(q)$ significantly different from unity is sufficient to reject the random walk hypothesis. Consider the observed log-prices series $L_o, L_1, \ldots L_n$, where the total number of observations equals n + 1. Define the unbiased estimations of μ, V(1) and V (q), respectively. Then:

$$\mu = 1/(n) \sum_{k=1}^{n} (L_k - L_{k-1}) \quad V(1) = 1/(n-1) \sum_{k=1}^{n} (L_k - L_{k-1} - \mu)^2$$

$$V(q) = 1/[q(n-q+1)(1-q/n)] \sum_{k=1}^{n} (L_k - L_{k-q} - q\mu)^2$$

As shown by Lo and MacKinlay (1988), the test statistic, z(q), whish is insensitive to non- normality of the underlying return distribution and overlapping data problem, is asymptotically normal with a mean of zero and variance of unity with the following specifications:

$$z(q) = [\lambda^*(q)/t(q)^{1/2}] \quad (6)$$

where

$$\lambda^*(q) = V(q)/[V(1)q] \quad (7)$$

$$t(q) = \sum_{j=1}^{q-1} [(2(q-j)/q]^2 d(j) \text{, and}$$

$$d(j) = \sum_{k=j+1}^{n} (L_k - L_{k-1} - \mu)^2 (L_{k-j} - L_{k-1} - \mu)^2 / [\sum_{k=j+1}^{n} (L_k - L_{k-1} - \mu)^2]^2$$

The estimations on the variance ratios of different lags, λ(q), and their associated test statistics, z(q), will allow us to assess if the variance ratios are significantly different from unity. The random walk hypothesis will be rejected if λ*(q) is significantly different from unity. Furthermore, an estimate of λ(q) greater (less) than 1 for q=2 would suggest significantly positive (negative) serial correlation between prices. Furthermore, the test is rather insensitive to heteroscedasticity, a phenomenon in which the variance changes over time, i.e., σ may itself be a random variable, possibly following a random walk or varying systematically with time. The estimations on the variance ratios of different lags, λ(q), and their associated tests statistics z(q) will allow us to determine whether the variance ratios are significantly different from unity.

To determine whether the systematic component in the original price series is not contributing to the price dependence measured by the variance ratios, the length of the different interval, q, must be significantly larger. However, the variance ratio would start from one (q=1) and exhibit deviations from one as q becomes larger, and eventually resolute back to one when q equals q*, where q* is the number of differences needed to randomize the original series. As q* is unknown if the underlying model is not first estimated, the evidence of deviations from unity for a given q only indicates the rejection of random walks *relative to* the holding period being investigated.

A. The Impact of the Bid-Ask Spreads

It should be noted, however, the existence of a nontrivial bid-ask spread, while not observable, complicates the measurement of the true variance ratio on the random element. This can be demonstrated by deriving the variance ratio from the specification of the variance function in equation (3) based on the observed prices:

$$\lambda(q) = (\sigma^2 + 2S^2(\sigma_\delta^2 - \rho_q)/q)/[\sigma^2 + 2S^2(\sigma_\delta^2 - \rho_1)] \tag{8}$$

Let

$$\lambda(q) = 1-\theta \tag{9}$$
$$\theta = 2S^2(\sigma_\delta^2 - \rho_1) - (\sigma_\delta^2 - \rho_q)/q/[\sigma^2 + 2S^2(\sigma_\delta^2 - \rho_1)].$$

where θ measures the bias from the bid-ask spread in the observed variance ratio. The observed variance in equation (4) is always upward biased for $\partial V(Rq)/\partial S > 0$. However, the variance ratio computed over the observed prices is biased downward since $\theta > 0$, for $q \geq 2$. This implies that $\lambda(q) \leq \lambda(q) = 1$ for any positive q greater or equal to 2, where $\lambda(q)$ is the true variance ratio associated with random walks independent of the bid-ask spread. Apparently, it is less interesting that the significant deviation of the variance ratio from unity is a result of simple measurement errors from bid-ask spreads. Since $\partial\theta/\partial q > 0$, the magnitude of the downward bias on the variance ratios increases as the number of lags increases. However, as $\partial V^2(Rq)/\partial q\partial S < 0$, the relative importance of the bias on the variance level also decreases when the number of lags increases. This would motivate the need of testing the hypothesis by computing the variance ratios of larger lags.

The bias from bid-ask spread components also varies with the length of the holding period for returns. From equation (3), the finite differenced log-prices over a longer horizon may be given as follows:

$$\text{Log}(P_t/P_{t-hq}) = \sum_{k=0}^{hq} \varepsilon t - k + (\delta t - \delta t - hq)S$$

where h is the number of periods in one holding horizon during which the return is measured and q is the number of lags taken on the longer horizon (h-period) returns. The variance ratio function specified by equation (8) can be modified as:

$$\lambda(q) = (\sigma^2 + 2S^2(\sigma_\delta^2 - \rho_q)/hq)/[\sigma^2 + 2S^2(\sigma_\delta^2 - \rho_1)/h]$$

and the bid-ask spread bias on the variance ratio over long-horizon returns as in equation (9) is

$$\theta_h = 2S^2[(\sigma_\delta^2 - \rho_1) - (\sigma_\delta^2 - \rho_q)/hq]/[\sigma^2 + 2S^2(\sigma_\delta^2 - \rho_1)/h]$$

Since $\partial\theta/\partial h < 0$, the downward bias on the variance ratio for *longer-horizon* returns less. This is mainly due to the non time-additive nature of the bid-ask spreads. The implication is that the impact of trading practice such as bid-ask spreads often dominates for the short-term holding period (Roll, 1984; Lehmann, 1989). Hence, the extent of a “manufactured” negative serial correlation from bid-ask spreads is expected to diminish significantly if the length of the holding period is extended. In short, to measure the time-series properties beyond the nontrivial impact of bid-ask spreads as well as the underlying systematic component, both the length of the holding period for the return and the lag for differencing should be significantly longer.

III. DATA

For the reasons discussed above, the weekly stock index levels of nine major foreign industrialized stock markets were gathered for the period 1981 to 2001. There are 1095 weekly Wednesday observations for each foreign stock market. The selection of the same weekday is based on the consideration that the confounding impact of the well-known day-of-the-week effect in major stock market indices can be minimized. These are Morgan Stanley Composite stock Indices obtained from Datastream. The nine stock markets are Belgium, Canada, France, Germany, Italy, Japan, Netherlands, Switzerland, and UK. These indices are all denominated in US dollars. Using stock indices, instead of individual stock prices, can also reduce the problem of the negative serial correlation in the individual stock price quotes.

IV. EMPIRICAL FINDINGS AND CONCLUSIONS

Based on the procedure described in the previous section, the variance ratios and their test statistics for lags 2 through 10 (q=2 to 10) are computed for each of the nine major foreign stock market indices. For the sake of brevity, we only report the variance ratios of one-week, two-week, and four-week returns for lag 2, 5 and 10 in Table 1 in Appendix. As the variance ratio for lag 2 can be approximated by 1-θ, where θ is the first-order autocorrelation, a variance ratio of 1.12 for Canada, for example, implies a 12 percent positive serial correlation between successive weekly price changes (returns). The results for weekly return reveal that none of the variance ratios are significantly different from one except for Canada.

While the weekly price changes may still be affected by the bid-ask spreads, the evidence on the bi-weekly returns shows a stronger pattern. Six out of the nine foreign stock indices (except for Netherlands, Italy and UK) exhibit significant positive serial correlations. These results are similar to the results obtained by Poterba and Summers (1988). However, they found negative autocorrelation over longer horizons. These results are not necessarily different from our results, since they also could not reject random-walk price behavior statistically. The inclusion of bid-ask spread may partially explain why we did not find negative autocorrelation over longer horizon. The robustness of the evidence can be further confirmed by the significant ratio when the lag is lengthened. Since the level of the downward bias from bid-ask spread would be greater when the lag is larger, the generally higher level of the variance ratios for the longer lags suggests that the variance ratio is least “contaminated” by the bid-ask spread problem, if it exists, in the data series. Therefore, this implies that the positive price dependence is very strong considering the impact of negative serial correlation due to the bid-ask spread. The persistence in the movements of stock indices is also consistent with the previous findings that portfolio returns exhibit positive serial correlation.

However, once the holding period extends to a month, the null hypothesis of random walks cannot be rejected. That is, almost all except one variance ratio are not different from one over shorter horizon but the hypothesis of random walk cannot be rejected over longer horizon.

To check the robustness of the results we divided the sample into pre and post 1987 crash. The estimated results of these two sub samples are presented in Tables 2 and 3. In the pre-crash period only 4 out of nine markets exhibit significant positive autocorrelation. However, in the post crash period seven out of nine markets show significant positive autocorrelation in bi-weekly holding period periods. In summary, similar to the recent findings in the U.S. stock market, we document significant evidence of deviations from random walks in the foreign stock markets.

REFERENCES

Alexander, S, 1961, "Price Movements in Speculative Markets: Trends or Random Walks," *Industrial Management Review* 2, 7-26.

Cecchetti, S., P. Lam and N. Mark, 1989, "Mean Reversion in Equilibrium Asset Prices." Working paper, Ohio State University.

Conrad, J. and G. Kaul, 1988, "Time-Variation in Expected Returns," *Journal of Business*, 61, 147-163.

Conrad, J., G. Kaul and M. Nimalendran, 1991, "Components of Short-Horizon Individual Security Returns," *Journal of Financial Economics*, 29, 365-385.

Fama, E., 1970, "Efficient Capital Markets: A Review of Theory and Empirical Work," *Journal of Finance*, 25, 383-417.

K. French, 1988, "Permanent and Temporary Components of Stock Prices," *Journal of Political Economy*, 96, 246-272.

French, K. and R. Roll, 1986, "Stock Return Variances: The arrival of Information and the Reaction of Traders," *Journal of Financial Economics*, 17, 5-26.

Houthakker, H., 1934, "Systematic and Random Elements in Short-Term Price Movements," *Journal of the American Statistical Association*, 29, 164-172.

Kendall, M., 1953, "The Analysis of Economic Time-Series, Part 1: Prices," *Journal of the Royal Statistical Society*, 96, 11-25.

Lehmann, B., 1990, "Fads, Martingales, and Market Efficiency," *Quarterly Journal of Economics*.

Lo, W. and C. Mackinlay, 1988, "Stock Market Prices Do Not Follow Random Walks: Evidence from a Simple Specification Test," *Review of Financial Studies*, 1, 41-66.

Ma, C., 1990, "Meant Reversions in GNMA Returns," *AREUEA*, 18, 207-226.

MacKinlay, C. and K. Ramaswamy, 1988, "Index-Futures Arbitrage and the Behavior of Stock Index Futures Prices," *Review of Financial Studies*, 1, 137-158.

Paterba, J.M. and L. H. Summers, 1988, "Mean Reversions in Stock Prices: Evidence and Implications," *Journal of Financial Economics*, 22, 27-59.

Powers, M., 1971, "Does Futures Trading Reduce Price Fluctuations in the Cash Markets?" *American Economics Review*, 61, 460-464.

Roberts, H., 1959, "Stock Market 'Pattern' and Financial Analysis: Methodological Suggestions," *Journal of Finance*, 14, 1-10.

Roll, R., 1984, "A Simple Measure of the Effective Bid-Ask Spread in an Efficient Market," *Journal of Finance*, 39, 1127-39.

Tintner, G., 1940, *The Variance Difference Method*, Bloomington.

Working, H., 1934, "A Random Difference Series for Use in the Analysis of Time Series," *Journal of the American Statistical Association*, 29, 11-24.

APPENDIX

Table 1
Variance ratio test for short-horizon foreign stock returns
sample period: January 1981 - December 2001

Country	Weekly Returns			Bi-Weekly Returns			Monthly Returns		
	q=2	q=5	q=10	q=2	q=5	q=10	q=2	q=5	q=10
Belgium	1.05	1.12	1.24	1.26	1.50	1.79	1.06	1.20	1.38
	0.74	1.27	1.68*	2.39*	2.74*	2.69*	0.43	0.94	1.14
Canada	1.12	1.23	1.32	1.18	1.25	1.30	1.05	1.04	1.03
	1.72*	2.18*	2.09*	1.75*	1.64	1.40	0.41	0.23	0.13
France	1.09	1.15	1.19	1.20	1.30	1.36	1.10	1.23	1.24
	1.34	1.53	1.36	1.98*	1.90*	1.61	0.73	1.06	0.81
Germany	1.05	1.07	1.07	1.19	1.28	1.33	1.00	0.99	0.88
	0.73	0.75	0.54	1.86*	1.82*	1.52	-0.03	-0.04	-0.56
Italy	1.05	1.14	1.12	1.08	1.25	1.34	0.99	1.07	1.04
	0.83	1.40	0.94	0.85	1.67*	1.53	-0.12	0.36	0.17
Japan	1.03	1.11	1.18	1.17	1.28	1.34	1.02	1.08	0.94
	0.47	1.16	1.33	1.72*	1.82*	1.54	0.13	0.42	-0.28
Netherlands	0.98	0.90	0.88	1.05	1.01	1.02	0.98	0.97	0.83
	-0.40	-1.37	-1.19	0.61	0.10	0.12	-0.19	-0.16	-0.83
Switzerland	1.05	1.07	1.09	1.18	1.25	1.31	1.06	1.17	1.14
	0.85	0.79	0.69	1.82*	1.68*	1.46	0.41	0.81	0.51
UK	0.95	0.91	0.81	1.01	0.98	0.89	1.05	1.12	0.99
	-0.80	-1.12	1.96*	0.13	-0.17	-0.78	0.36	0.60	-0.03

The tests are performed from lag 2 (q=2) through 10. Only three representative lags are reported.
The variance ratio is computed by equation (7).
The Z- statistic reported below the variance ratio is computed using equation (6).
* Significant at the 5 percent level.

Table 2
Variance ratio test for short-horizon foreign stock returns
sample period: January 1981 - September 1987

Country	Weekly			Bi-Weekly Returns			Monthly Returns		
	q=2	q=5	q=10	q=2	q=5	q=10	q=2	q=5	q=10
Belgium	1.19	1.41	1.68	1.26	1.48	1.67	0.99	1.02	1.07
	1.49	1.92*	1.98*	1.38	1.53	1.39	-0.03	0.06	0.14
Canada	1.20	1.38	1.60	1.07	1.07	1.10	1.04	0.99	0.86
	1.57	1.83*	1.83*	0.41	0.30	0.31	0.19	-0.03	-0.38
France	1.23	1.40	1.62	1.15	1.28	1.26	0.99	1.04	1.05
	0.69	1.91*	4.75*	0.84	1.02	0.72	-0.05	0.11	0.10
Germany	1.07	1.14	1.18	1.01	0.97	0.79	0.89	0.93	0.88
	0.59	0.81	0.75	0.06	-0.13	-0.91	-0.54	-0.23	-0.33
Italy	1.06	1.29	1.47	0.99	1.11	1.11	1.02	0.99	0.96
	0.56	1.50	1.57	-0.08	0.47	0.35	0.09	-0.04	-0.10
Japan	1.24	1.39	1.49	1.05	1.05	0.85	0.85	0.78	0.71
	1.82	1.87*	1.61	0.29	0.24	-0.62	-0.81	-0.89	-0.95
Netherlands	0.98	0.93	0.93	0.99	1.00	0.85	0.94	0.79	0.63
	-0.21	-0.47	-0.38	-0.04	0.01	-0.61	-0.30	-0.83	-1.35
Switzerland	1.11	1.18	1.35	1.08	1.14	0.96	0.86	1.02	1.28
	0.95	1.00	1.27	0.49	0.58	-0.16	-0.66	0.05	0.51
UK	0.89	0.87	0.84	1.08	1.13	1.02	0.96	0.94	0.87
	-1.11	-1.02	-0.92	0.50	0.54	0.06	-0.18	-0.19	-0.36

The tests are performed from lag 2 (q=2) through 10. Only three representative lags are reported.
The variance ratio is computed by equation (7).
The Z- statistic reported below the variance ratio is computed using equation (6).
* Significant at the 5 percent level.

Table 3
Variance ratio test for short-horizon foreign stock returns
sample period: November 1987 - December 2001

Country	Weekly			Bi-Week Returns			Monthly Returns		
	q=2	q=5	q=10	q=2	q=5	q=10	q=2	q=5	q=10
Belgium	0.94	0.92	0.93	1.21	1.38	1.60	1.05	1.20	1.28
	-0.93	-0.87	-0.54	1.66*	1.88*	1.87*	0.33	0.76	0.74
Canada	1.03	1.11	1.17	1.27	1.42	1.50	1.07	1.08	1.10
	0.42	0.98	1.01	2.07*	2.00*	1.67*	0.40	0.33	0.31
France	0.95	0.90	0.81	1.26	1.34	1.47	1.13	1.27	1.24
	-0.73	-1.11	-1.62	2.00*	1.71*	1.61	0.74	0.99	0.65
Germany	0.98	0.95	0.90	1.26	1.40	1.51	0.99	0.92	0.61
	-0.22	-0.53	-0.78	2.00*	1.93*	1.70*	-0.09	-0.38	-1.38
Italy	1.03	1.04	0.91	1.15	1.39	1.58	0.94	1.01	0.99
	0.42	0.37	-0.67	1.27	1.90*	1.84*	-0.40	0.05	-0.03
Japan	0.95	0.99	1.02	1.20	1.33	1.46	1.09	1.19	0.90
	-0.78	-0.09	0.11	1.63	1.69*	1.57	0.52	0.72	-0.36
Netherlands	0.93	0.79	0.72	1.09	1.00	1.06	0.98	1.00	0.85
	-1.09	-2.51*	-2.75*	0.76	-0.01	0.28	-0.12	0.01	-0.62
Switzerland	1.00	0.99	0.93	1.25	1.32	1.50	1.08	1.15	0.97
	-0.06	-0.13	-0.52	1.95*	1.66*	1.67*	0.48	0.61	-0.12
UK	0.95	0.91	0.78	0.99	0.92	0.86	1.08	1.20	1.06
	-0.68	-0.98	-1.95*	-0.09	-0.63	-0.82	0.50	0.77	0.18

The tests are performed from lag 2 (q=2) through 10. Only three representative lags are reported.
The variance ratio is computed by equation (7).
The Z- statistic reported below the variance ratio is computed using equation (6).
* Significant at the 5 percent level.