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An empirical note on the random walk behaviour and market efficiency of Latin American stock markets

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This note examines the weak-form market efficiency of Latin American equity markets. Daily returns for Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela are examined for random walks using serial correlation coefficient and runs tests, Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski, Phillips, Schmidt and Shin (KPSS) unit root tests and multiple variance ratio (MVR) tests. The results, which are in broad agreement across the approaches employed, indicate that none of the markets are characterised by random walks and hence are not weak-form efficient, even under some less stringent random walk criteria.

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JEL classifications: C12, C14, G14, G15.

INTRODUCTION

Much of the evidence regarding the random walk behaviour of stock returns has been garnered from developed markets. While the focus of research has now shifted towards emerging markets, largely in recognition of the valuable contribution efficient markets can play in financial development and economic growth, stock markets in Latin America have received less attention than that elsewhere. The evidence that does exist is incomplete in that it focuses on a small number of markets, draws upon low frequency and short sample data, and relies on a narrow range of empirical techniques. In evidence, Urrutia (1995), Ojah and Karemera (1999) Karemera et al. (1999) examined random walk behaviour in only four Latin American markets using just variance ratio tests, and while Haque's et al. (2001) analysis added another three markets, none of these studies employed data with a higher frequency than weekly or with a sample longer than a decade. Barry and Rodriguez (1997), Grieb and

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Reyes (1999), Pagán and Soydemir (2000, 2001) and Curci et al. (2002) have examined Latin American stock markets from a similar perspective.

To meet this deficiency, this note examines the random walk behaviour of seven Latin American stock markets (Argentina, Brazil, Chile, Columbia, Mexico, Peru and Venezuela) using daily data for up to a fifteen-year period and three sets of alternative, though complementary, testing procedures. The remainder of this note is divided into four sections. The first section provides a description of the data employed in the analysis. The next section discusses the empirical methodology used. The results are dealt with in the third section. The paper ends with some concluding remarks in the final section.

DESCRIPTION AND PROPERTIES OF THE DATA

The data employed in the study is composed of market value-weighted equity indices for seven emerging Latin American markets; namely, Argentina (ARG), Brazil (BRZ), Chile (CHL), Columbia (COL), Mexico (MEX), Peru (PRU), Venezuela (VEN). 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 ARG, BRZ, CHL and MEX commencing on 31-Dec-1987 and COL, PRU and VEN on 31-Dec-1992. MSCI indices are widely employed in the financial literature on the basis of the degree of comparability and avoidance of dual listing, and are constructed to overcome problems associated with infrequent or non-synchronous trading in markets.

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 $p_{t\text{-}1}$ 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 seven markets. Sample means, maximums, minimums, standard deviations, skewness, kurtosis and Jacque-Bera statistics and p-values are reported. The lowest mean returns are in Columbia (-0.0001) Venezuela (0.0000) and the highest mean returns are for Argentina (0.0004) and Mexico (0.0006). The lowest minimum returns are in Argentina (-0.9270) and Venezuela (-0.7124) as are the highest maximum returns (0.4559 and 0.2137, respectively). The standard deviations of returns range from 0.0127 (Chile) to 0.0401 (Argentina). On this

basis, of the seven markets the returns in Chile, Columbia and Peru are the least volatile, with Venezuela, Brazil and Argentina being the most volatile.

<TABLE 1 HERE>

By and large, the distributional properties of all seven 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 Mexico and Peru, are significantly skewed. Venezuela, Argentina, Chile and Brazil are negatively skewed, indicating the greater probability of large deceases in returns than rises, while Columbia is 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 9.0184 for Peru to 153.7496 for Venezuela, thereby indicating leptokurtic distributions. 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.

EMPIRICAL METHODOLOGY

Random walk hypothesis

Consider the following random walk with drift process:

$$p_t = p_{t-1} + \beta + \varepsilon_t \tag{1}$$

or

$$r_t = \Delta p_t = \beta + \varepsilon_t \tag{2}$$

where p_t is the price of the 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 $E(\varepsilon_t) = 0$ and $E(\varepsilon_t \varepsilon_{t-g}) = 0$, $g \neq 0$, 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.

Within the random walk hypothesis, three successively more restrictive sub-hypotheses with sequentially stronger tests for random walks exist (Campbell et al. 1997). 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. That is, returns in a market conforming to this standard of random walk are serially uncorrelated, corresponding to a random walk hypothesis with dependent but uncorrelated increments. 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. 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. In this market, returns are serially uncorrelated and conform to a random walk hypothesis with independent and identically distributed increments.

This provides a number of complementary testing procedures for random walks or weak-form market efficiency. To start with, the parametric serial correlation test of independence and the non-parametric runs test can be used to test for serial independence in the series. Alternatively, 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, multiple variance ratio procedures can focus attention on the uncorrelated residuals in the series, under assumptions of both homoskedastic and heteroskedastic random walks.

Tests of serial independence

Two approaches are employed to test for serial independence in the returns. 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. In the approach selected, each return is classified according to its position with respect to the mean return. That is, a positive change is when the return is greater than the mean, a negative

change when the return is less than the mean, and zero change when the return equals the mean.

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 large sample sizes, 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 $\mu_{\mathrm{U}} = \frac{2n_A n_B}{n} + 1$, $\sigma_U = \sqrt{\frac{2n_A n_B (2n_A n_B - n)}{n^2 (n-1)}}$ and $n = n_A + n_B$

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, the Phillips-Peron (PP) test, and the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test. 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 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 test differs from these other unit root tests in that the series is assumed to be stationary under the null.

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) earlier single variance ratio (VR) test, Chow and Denning (1993) adjusts the focus of the tests from the individual variance ratio for a specific interval to one more consistent with the random walk hypothesis by 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 return 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 $VR(q) = 1$. For a sample size of $nq + 1$ observations (p_0, p_1, …, p_{nq}), Lo and Mackinlay's (1988) unbiased estimates of $\sigma^2(1)$ and $\sigma^2(q)$ are computationally denoted by:

$$\hat{\sigma}^2(1) = \frac{\sum_{k=1}^{nq}(p_k - p_{k-1} - \hat{\mu})^2}{(nq-1)} \tag{7}$$

and

$$\hat{\sigma}^2(q) = \frac{\sum_{k=q}^{nq}(p_k - p_{k-q} - q\hat{\mu})^2}{h} \tag{8}$$

where $\hat{\mu} = \text{sample mean of } (p_t - p_{t-1})$ and:

$$h \equiv q(nq+1-q)(1-\frac{q}{nq}) \tag{9}$$

Lo and Mackinlay (1988) produce two test statistics, $Z(q)$ and $Z^*(q)$, under the null hypothesis of homoskedastic increments random walk and heteoskedastic increments random walk respectively. If the null hypothesis is true, the associated test statistic has an asymptotic standard normal distribution. With a sample size of $nq + 1$ observations (p_0, p_1, …,p_{nq}) and under the null hypothesis of homoskedastic increments random walk, the standard normal test statistic $Z(q)$ is:

$$Z(q) = \frac{V\hat{R}(q) - 1}{\hat{\sigma}_0(q)} \tag{10}$$

where

$$\hat{\sigma}_0(q) = \left[\frac{2(2q-1)(q-1)}{3q(nq)} \right]^{1/2} \tag{11}$$

The test statistic for a heteroskedastic increments random walk, $Z^*(q)$ is:

$$Z^*(q) = \frac{V\hat{R}(q) - 1}{\hat{\sigma}_e(q)} \tag{12}$$

where

$$\hat{\sigma}_e(q) = \left[4\sum_{k=1}^{q-1} \left(1 - \frac{k}{q} \right)^2 \hat{\delta}_k \right]^{1/2} \tag{13}$$

and

$$\hat{\delta}_k = \frac{\sum_{j=(k+1)}^{nq} (p_j - p_{j-1} - \hat{\mu})^2 (p_{j-k} - p_{j-k-1} - \hat{\mu})^2}{\left[\sum_{j=1}^{nq} (p_j - p_{j-1} - \hat{\mu})^2 \right]^2} \tag{14}$$

Lo and MacKinlay's (1988) procedure is devised to test individual variance ratios for a specific aggregation interval, q, but the random walk hypothesis requires that $VR(q) = 1$ for all q. Chow and Denning's (1993) multiple variance ratio (MVR) test generates 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:

$$\begin{aligned} &H_{oi}: \quad M_r(q_i) = 0 \qquad \text{for } i = 1,2,\ldots,m \\ &H_{1i}: \quad M_r(q_i) \neq 0 \qquad \text{for any } i = 1,2,\ldots,m \end{aligned} \tag{15}$$

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. Hence only the maximum absolute value in the set of test statistics is considered. The core of the Chow and Denning's (1993) MVR test is based on the result:

$$PR\{\max(|Z(q_1)|,\ldots,|Z(q_m)|) \leq SMM(\alpha;m;T)\} \geq 1 - \alpha \tag{16}$$

where *SMM(α;m;T)* is the upper α point of the Standardized Maximum Modulus (*SMM*) distribution with parameters *m* (number of variance ratios) and *T* (sample size) degrees of freedom. Asymptotically when *T* approaches infinity:

$$\lim_{T\to\infty} SMM(\alpha;m;\infty) = Z_{\alpha^*/2} \tag{17}$$

where $Z_{\alpha^*/2}$ = standard normal distribution and $\alpha^* = 1-(1-\alpha)^{1/m}$. 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 *SMM* critical values. If the maximum absolute value of, say *Z(q)* is greater than the *SMM* critical value than the random walk hypothesis is rejected.

Importantly, the rejection of the random walk under homoskedasticity could result from either heteroskedasticity and/or autocorrelation in the equity price series. If the heteroskedastic random walk is rejected than there is evidence of autocorrelation in the equity series. With the presence of autocorrelation in the price series, the first order autocorrelation coefficient can be estimated using the result that $\hat{M}_r(q)$ is asymptotically equal to a weighted sum of autocorrelation coefficient estimates with weights declining arithmetically:

$$\hat{M}_r(q) = 2\sum_{k=1}^{q-1}\left(1-\frac{k}{q}\right)\hat{\rho}(k) \tag{18}$$

where q = 2:

$$\hat{M}_r(2) \equiv V\hat{R}(2) - 1 = \hat{\rho}(1) \tag{19}$$

EMPIRICAL RESULTS

Table 2 provides two sets of test statistics. The first set includes the statistics and *p*-values for the tests of serial independence, namely, the parametric serial correlation coefficient and the nonparametric one sample runs test. The null hypothesis in the former is for no serial correlation while in the latter it is the random distribution of returns. The second set of tests is unit root tests and comprises the ADF and PP *t*-statistics and *p*-values and the KPSS *LM*-statistic and asymptotic significance. 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).

<TABLE 2 HERE>

Turning first to the tests of independence, the null hypotheses of no serial correlation for Brazil, Chile, Columbia, Mexico, Peru and Venezuela are rejected at the .01 level or higher,

while that for Argentina is rejected at the .05 level or higher. 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 seven Latin American markets are weak-form inefficient.

With the exception of Argentina, all of the coefficients are positive indicating persistence in returns, with persistence being higher in Columbia (0.3390) and Chile (0.2270) and lower in Brazil (0.1520) and Mexico (0.1230). The average persistence is 0.1858 across all six markets. For Argentina the serial correlation coefficient of -0.0310 is indicative of a mean reversion process. However, it should be noted that over shorter horizons the six markets exhibiting persistence (and Argentina exhibiting mean-reversion) could also display mean-reversion (persistence). In terms of the runs tests, the negative *z*-values for all of the markets, including Argentina, indicates that the actual number of runs falls short of the expected number of runs under the null hypothesis of return independence at the .01 level or lower for all markets. These indicate positive serial correlation. We likewise reject the null hypothesis of weak-form efficiency when employing the nonparametric assumptions entailed in runs tests. By way of comparison, Karemera et al. (1999) also used runs tests (though with monthly returns) to conclude that Argentina, Brazil and Mexico were weak form efficient from an international investor's perspective (when measured in US dollars) while Brazil and Mexico were weak-form efficient in local currency terms. Urrutia's (1995) runs tests likewise failed to reject the null hypothesis of independence for Argentina, Brazil, Chile and Mexico.

The unit root tests in Table 2 are also supportive of the hypothesis that Latin American equity markets are not weak form efficient. The ADF and PP *t*-statistics reject the null hypotheses of a unit root at the .01 level or lower, thereby indicating that all of the return series examined are stationary. For the KPSS tests of the null hypothesis of no unit root, the *LM*-statistic exceeds the asymptotic critical value at the .05 level for Chile (0.6839) and at the .10 level for Argentina (0.3925) and Mexico (0.5410). As a necessary condition for a random walk, the ADF and PP unit root tests reject the requisite null hypothesis in the case of all seven markets, while the KPSS unit root tests fail to reject the required null with the exception of the Argentina, Chile and Mexico.

Table 3 presents the results of the multiple variance ratio tests of returns in the seven Latin American markets. The sampling intervals for all markets are 2, 5, 10 and 20 days, corresponding to one-day, one week, one fortnight and one month calendar periods. For each interval Table 3 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 2,714 observations (Columbia, Peru and Venezuela) 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 3 HERE>

Consider the results for Mexico. The null hypothesis that daily equity returns follow a homoskedastic random walk is rejected at Z(2) = 7.8833. Rejection of the null hypothesis of a random walk under homoskedasticity for a 2-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 Mexican 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*(2) = 3.6223. The heteroskedastic random walk hypothesis is thus rejected because of autocorrelation in the daily increments of the returns on Mexican equity. We may conclude that the Mexican 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 [Mexico's serial correlation coefficient in Table 2 is 0.1230]. On this basis, the estimated first order autocorrelation coefficient is 0.1244 corresponding to the estimated variance ratio $V\hat{R}(2)$ of 1.1244 (i.e. 1.1244 - 1.0000). Further, 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 positive autocorrelation (or persistence) in Mexican equity returns over the long horizon.

By way of comparison, observe the results for Argentina. The null hypothesis that daily equity returns follow a homoskedastic random walk is rejected at Z(5) = -4.8571 which in absolute terms is greater than the critical value of 2.49. This likewise suggests that the Argentinean equity market is weak form inefficient. However, the null hypothesis of a heteroskedastic random walk is not rejected [*Z*(q)*=-1.5782]. 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 autocorrelation in returns. In addition, since $V\hat{R}(2) < 1$ for Argentina we can infer that its market returns are characterised by mean reversion (i.e. 0.9698 - 1.0000 = 0.0302).

Of the seven markets, the multiple variance ratios testing procedure rejects the null hypothesis of a random walk under assumptions of both homoskedasticity and heteroskedasticity for all except Argentina. We may then conclude that none of these markets are weak form efficient. With Argentina the null hypothesis of a homoskedastic random walk is rejected, but not that for a heteroskedastic random walk. This infers that the observed random walk violation could be the result of heteroskedasticity and autocorrelation in daily returns, thereby corresponding to a less stringent version of the random walk hypothesis. Nevertheless, the multiple variance ratio technique indicates the presence of positive autocorrelation (or persistence) in six markets and negative autocorrelation (or mean reversion) for Argentina and thereby provides comparable evidence to the results of the serial correlation coefficients and runs tests. They do however strongly contradict the earlier evidence provided by Urrutia (1995) Ojah and Karemera (1999) that Argentina, Brazil, and Chile were weak form efficient, and by Urrutia (1995) and Karemera et al. (1999) that Mexico was also weak form inefficient. They do, however, substantiate Haque et al. (2001) conclusion that all of these markets are no weak form efficient on the basis of testing the earlier Lo and MacKinlay (1988) single variance ratio procedure using weekly returns.

CONCLUSION

This note examines the weak form market efficiency of seven Latin American equity markets; namely, Argentina, Brazil, Chile, Columbia, Mexico, Peru and Venezuela. Three different procedures are employed to test strict and less strict versions of the random walk hypothesis in daily returns: (i) the parametric serial correlation coefficient and the nonparametric runs test are used to test for serial correlation; (ii) Augmented Dickey-Fuller, Phillips-Perron and Kwiatkowski, Phillips, Schmidt and Shin unit root tests are used to test for non-stationarily as a necessary condition for a random walk; and (iii) multiple variance test statistics are used to test for random walks under varying distributional assumptions. The results for the tests of serial correlation are in broad agreement, conclusively rejecting the presence of random walks in daily returns in the seven emerging markets. Similarly, the unit root tests conclude that unit roots, as necessary conditions for a random walk, are absent from all of the return series. Finally, the multiple variance ratio procedure conclusively rejects the presence of random

walks in any Latin American market, though a random walk in the Argentinean market is rejected under less restrictive criteria than the remaining markets.

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TABLE 1. *Descriptive statistics for Latin American markets*

Market	Start	End	Observations	Mean	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	JB *p*-value
ARG	31-Dec-1987	28-May-2003	4019	4.52E-04	0.4559	-0.9270	0.0401	-2.8730	95.1709	1.43E+06	0.0000
BRZ	31-Dec-1987	28-May-2003	4019	3.98E-04	0.2123	-0.2635	0.0288	-0.4078	10.6391	9.88E+03	0.0000
CHL	31-Dec-1987	28-May-2003	4019	4.19E-04	0.0870	-0.1623	0.0127	-0.4897	14.1018	2.08E+04	0.0000
COL	31-Dec-1992	28-May-2003	2714	-8.87E-05	0.1329	-0.0735	0.0132	0.3010	11.0072	7.29E+03	0.0000
MEX	31-Dec-1987	28-May-2003	4019	6.87E-04	0.1784	-0.2176	0.0196	-0.0669	15.4183	2.58E+04	0.0000
PRU	31-Dec-1992	28-May-2003	2714	2.69E-04	0.1065	-0.0930	0.0160	0.0579	9.0184	4.10E+03	0.0000
VEN	31-Dec-1992	28-May-2003	2714	8.45E-06	0.2137	-0.7124	0.0284	-5.3078	153.7496	2.58E+06	0.0000

Notes: ARG – Argentina, BRZ – Brazil, CHL – Chile, COL – Columbia, MEX – Mexico, PRU – Peru, VEN – Venezuela. JB – Jarque-Bera. Critical values for significance of skewness and kurtosis at the .05 level are 0.0757 and 0.1514 for ARG, BRZ, CHL and MEX and 0.0921 and 0.1843 for COL, PRU and VEN.

TABLE 2. *Tests of independence and unit root tests for Latin American markets*

	Serial correlation		Runs test							Unit root tests					
Market	Coefficient	*p*-value	Mean	Cases < mean	Cases ≥ mean	Total cases	Number of runs	Runs Z-value	*p*-value	ADF *t*-statistic	ADF *p*-value	PP *t*-statistic	PP *p*-value	KPSS *LM*-statistic	KPSS significance
ARG	-0.0310	0.0247	4.52E-04	2106	1913	4019	1867	-4.3916	0.0000	-38.1018	0.0000	-66.0677	0.0001	0.3925	0.1000
BRZ	0.1520	0.0000	3.98E-04	2054	1965	4019	1791	-6.8979	0.0000	-54.3501	0.0001	-55.0195	0.0001	0.1234	–
CHL	0.2270	0.0000	4.19E-04	2126	1893	4019	1585	-13.2568	0.0000	-50.1775	0.0001	-50.2673	0.0001	0.6839	0.0500
COL	0.3390	0.0000	-8.87E-05	1315	1399	2714	1043	-12.0569	0.0000	-36.5759	0.0000	-37.4777	0.0000	0.1244	–
MEX	0.1230	0.0000	6.87E-04	2074	1945	4019	1775	-7.3727	0.0000	-55.9574	0.0001	-55.8887	0.0001	0.5410	0.0500
PRU	0.1810	0.0000	2.69E-04	1404	1310	2714	1245	-4.2816	0.0000	-43.3626	0.0000	-43.2109	0.0000	0.1628	–
VEN	0.0930	0.0000	8.45E-06	1454	1260	2714	1185	-6.4093	0.0000	-45.5321	0.0001	-45.3040	0.0001	0.0414	–

Notes: ARG – Argentina, BRZ – Brazil, CHL – Chile, COL – Columbia, MEX – Mexico, PRU – Peru, VEN – Venezuela. For Augmented Dickey-Fuller (ADF) tests 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 3. *Multiple variance ratio tests for Latin American markets*

Market	Statistics	q = 2	q = 5	q = 10	q = 20
ARG	VRq	0.9698	0.8321	0.7445	0.7630
	Zq	-1.9147	*-4.8571	-4.7980	-3.0226
	Z*q	-0.6659	-1.4829	-1.5782	-1.0872
BRZ	VRq	1.1530	1.3386	1.4444	1.5376
	Zq	9.6965	*9.7974	8.3445	6.8571
	Z*q	5.0969	*5.3539	4.9252	4.3488
CHL	VRq	1.2299	1.3986	1.5281	1.7725
	Zq	*14.5756	11.5350	9.9155	9.8541
	Z*q	*9.4875	7.7593	7.0012	7.4213
COL	VRq	1.3402	1.8039	2.0702	2.4869
	Zq	17.7205	*19.1145	16.5124	15.5860
	Z*q	10.1606	*11.9481	11.0265	11.0981
MEX	VRq	1.1244	1.1939	1.2105	1.3425
	Zq	*7.8833	5.6113	3.9516	4.3690
	Z*q	*3.6223	2.8368	2.1745	2.5795
PRU	VRq	1.1818	1.2814	1.2651	1.3679
	Zq	*9.4709	6.6907	4.0902	3.8568
	Z*q	*5.8074	4.3022	2.7807	2.7895
VEN	VRq	1.1342	1.1300	1.1495	1.1610
	Zq	*6.9890	3.0900	2.3061	1.6876
	Z*q	*4.0589	1.8932	1.5833	1.2960

Notes: ARG – Argentina, BRZ – Brazil, CHL – Chile, COL – Columbia, MEX – Mexico, PRU – Peru, VEN – Venezuela. 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, asterisk indicates significance at this level; Sampling intervals (q) are in days.