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Evaluating financial development in emerging capital markets with efficiency benchmarks

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Evaluating financial development in emerging capital markets with efficiency benchmarks

Abstract
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EVALUATING FINANCIAL DEVELOPMENT IN EMERGING CAPITAL MARKETS WITH EFFICIENCY BENCHMARKS

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This paper examines the weak-form market efficiency of twenty-seven emerging markets. The sample encompasses three markets in Africa (Egypt, Morocco and South Africa), ten in Asia (China, India, Indonesia, Korea, Malaysia, Pakistan, the Philippines, Sri Lanka, Taiwan and Thailand), four in Europe (Czech Republic, Hungary, Poland and Russia), seven in Latin America (Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela) and three in the Middle East (Israel, Jordan and Turkey). Daily market returns are tested 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 tests. The serial correlation and runs tests conclude that most emerging markets are weak-form inefficient. However, the unit root tests suggest the presence of weak-form efficiency in many emerging markets, but with some exceptions. The results from the most stringent multiple variance ratio tests are in general agreement with the serial correlation and runs tests. On this basis, only Hungary, Jordan and Israel are weak-form market efficient, with Egypt, Korea, Malaysia and Argentina meeting at least some of the requirements of a random walk.

Keywords: Market efficiency, Random walks, Emerging markets.

JEL classification: C10, G14, O16

1. INTRODUCTION

Stock markets play a crucial role in financial development. However, the ability of stock markets to play the role that is ascribed to them – attracting foreign investment, boosting domestic saving and improving the pricing and availability of capital – depends upon the presence of market efficiency. In an efficient market, the prices of stocks fully incorporate all relevant information, and hence stock returns will display unpredictable (or random walk) behaviour. A market following a random walk is consistent with equity being appropriately priced at an equilibrium level, whereas the absence of a random walk infers distortions in the pricing of capital and risk. This has important implications for the allocation of capital within an economy and hence overall financial development.

In this manner, tests of market efficiency and, more particularly, random walks, provide an important means by which financial development can be appraised. Only in fully deregulated and liberalised markets characterised by appropriate incentives and institutional

frameworks can we expect the necessary prerequisites for market efficiency – including market liquidity, breadth and depth – to be satisfied. But the issue of how efficient markets actually are in the real world is clearly a question that can only be resolved by resorting to empirical evidence. This can be problematic in that the measurement of market efficiency is beset with a number of conceptual and methodological difficulties.

In this paper an attempt is made to examine the random walk behaviour (and hence market efficiency) of emerging markets using a number of alternative, though complementary, testing procedures. The paper itself is divided into five main areas. Section 2 provides a synoptic review of the different techniques for the measurement of market efficiency on the basis of random walks and deals with the literature on the empirical measurement of market efficiency. Section 3 provides a description of the data employed in the analysis. Section 4 discusses the empirical methodology used. Attention is paid to the four types of tests employed and their differing assumptions regarding the random walk hypothesis. The results are dealt with in Section 5. The paper ends with some concluding remarks in the final section.

2. RANDOM WALKS AND MARKET EFFICIENCY

Random walks in stock returns are crucial to the formulation of rational expectations models and the testing of (weak-form) market efficiency. In an efficient market, the prices of stocks fully incorporate all relevant information, and hence stock returns will display unpredictable (or random walk) behaviour. In stock prices not characterised by a random walk the return generating process is dominated by a temporary component and therefore future returns can be predicted by the historical sequence of returns. Tests for weak form market efficiency then focus on the predictability of stock returns.

Despite its apparent singularity, the random walk model actually comprises three successively more restrictive hypotheses with sequentially stronger tests for random walks (Campbell et al. 1997). 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 (RW3). That is, returns in a market conforming to RW3 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 independently, but not identically, distributed (RW2). 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 (RW1). In such a market, returns are serially uncorrelated and conform to a random walk hypothesis with independent and identically distributed increments.

A variety of tests have been employed within this framework to examine random walks (and hence tests for weak-form efficiency) in real-world markets (Fama 1970; 1991). One approach is to test the serial correlation of returns. Since under the random walk hypothesis the increments are uncorrelated at all leads and lags, autocorrelation tests form the basis of a large number of studies. Another approach is to examine the sequence of returns, of which the runs test is well known. This is regarded as a more appropriate test of the assumption of independence under the non-normal distribution of returns. However, more recent work often employs variance (or multiple variance) ratio and unit root tests. An important property of the former is that it entails testing not only the RW1 hypothesis, but also RW2 and RW3. In the case of the latter, though they imply non-zero serial autocorrelation under both the null and alternative hypothesis, they are useful for the identification of nonstationarity as a necessary condition for a random walk, with other tests used to verify the independence assumption.

To this end, an ever-increasing number of studies have examined random walks in the world's stock markets. Some of these have chosen to concentrate on individual markets. These include studies of random walks in Korea (Ayadi and Pyun 1994, Ryoo and Smith 2002), China (Lee et al. 2001), Hong Kong (Cheung and Coutts 2001), Slovenia (Dezlan 2000), Spain (Regúlez and Zarraga 2002), the Czech Republic (Hajek 2002), the United Kingdom (Poon 1996) and Turkey (Zychowicz et al. 1995, Buguk and Brorsen 2003). Others have elected instead to focus on emerging markets on a regional basis. Markets in Asia (Huang 1995, Groenewold and Ariff 1998), Latin America (Urrutia 1995, Ojah and Karemera 1999. Grieb and Reyes 1999, Karemera et al. 1999), Africa (Smith et al. 2002, Appiah-Kusi and Menyah 2003) and the Middle East (Abraham et al. 2002) have been addressed in this manner. However, these studies generally concentrate on developed markets and none have examined a large number of markets across regions.

Similarly, with few exceptions these studies have employed a single testing procedure for random walks and market efficiency. Some, such as Poshakwale (1996) and Abraham et al. (2002), have concentrated on tests for serial dependence, while others, including Karemara et al. (1999) and Ryoo and Smith (2002), have employed variance ratio tests. The low power

of unit root tests and the restrictive assumptions of tests for serial dependence are well known, but even the variance ratio test (as against multiple variance ratio tests) is shown to be inexact under certain conditions. In addition, nearly all of these studies have specified returns as weekly or longer. For example, Karemara et al. (1999) employed monthly data, while Los (2000), Abraham et al. (2002) and Ryoo and Smith (2002) used weekly. An obvious qualification is the lack of suitable return series in the past, seeing as some random walk tests have been shown to be imprecise in the presence of infrequent or non-synchronous trading. Nevertheless, this is still an important omission since it is likely that some violations of the random walk hypothesis are likely to be obscured at the longer sampling frequencies.

3. DESCRIPTION AND PROPERTIES OF THE DATA

The data employed in the study is composed of market value-weighted equity indices for twenty-seven emerging markets. Three of these markets are in Africa (EGY – Egypt, MOR – Morocco, SAF – South Africa), ten in Asia (CHN – China, IND – India, INA – Indonesia, KOR – Korea, MLY – Malaysia, PAK – Pakistan, PHL – Philippines, SRI – Sri Lanka, TWN – Taiwan, THA – Thailand), four in Europe (CZH – Czech Republic, HGY – Hungary, POL – Poland, RUS – Russia), seven in Latin America (ARG – Argentina, BRZ – Brazil, CHL – Chile, COL – Columbia, MEX – Mexico, PRU – Peru, VEN – Venezuela) and three in the Middle East (ISR – Israel, JOR – Jordan, TUR – Turkey). 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 EGY commencing on 1-Sep-1997, PAK on 1-Nov-1995, MOR, CZH, HGY and RUS on 2-Jan-1995, SAF, CHN, IND, SRI, POL, COL, PRU, VEN and ISR on 1-Jan-1998 and the remaining markets on 31-Dec-1987. 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 trading in markets.

Daily data is specified. By way of comparison, Poshakwale (1996) and Cheung and Coutts (2001) also used daily returns to test for random walks in emerging markets. 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. Figure 1 includes graphs of all series. Table 1 presents a summary of descriptive statistics of the daily returns for the twenty-

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 China (-0.0007), Egypt (-0.0006) and Pakistan (-0.0002) and the highest mean returns are for Hungary (0.0005), Russia (0.0006) and Mexico (0.0007). The lowest minimum returns are in Argentina (-0.9270), Venezuela (-0.7124) and Indonesia (-0.4308), and the highest maximum returns are in Hungary (0.3796), Indonesia (0.4551) and Argentina (0.4559). The standard deviations of returns range from 0.0077 (Morocco) to 0.0401 (Argentina). On this basis, of the twenty-seven markets the returns in Morocco, Jordan and Chile are the least volatile, with Turkey, Russia and Argentina being the most volatile.

<TABLE 1 HERE>

By and large, the distributional properties of all twenty-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 Taiwan, Mexico and Peru, are significantly skewed. Indonesia, China, Egypt, Columbia, Korea, Morocco, Thailand, Philippines, Sri Lanka and Hungary are positively skewed, indicating the greater probability of large increases in returns than falls, while the remaining markets are negatively skewed, signifying the greater likelihood of large decreases in returns than rises. The kurtosis, or degree of excess, in all market returns is also large, ranging from 5.0435 for the Czech Republic to 309.6680 for Jordan, 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.

4. EMPIRICAL METHODOLOGY

4.1 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 logarithm of the index price 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. In the strictest version of the efficient market hypothesis, ε_t is not only random and stationary, but exhibits no autocorrelation, since the disturbance term cannot possess any systematic forecast errors. This provides three 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 dependence 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.

4.2 Serial dependence tests

Two approaches are employed to test for serial dependence 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 $\mu_U = \frac{2n_A n_B}{n} + 1$, $\sigma_U = \sqrt{\frac{2n_A n_B (2n_A n_B - n)}{n^2 (n-1)}}$ and $n = n_A + n_B$

4.3 Unit root tests

Three different unit root tests are used to test the null hypothesis of a unit root or random walk: 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 or random walk is conducted in the form of the following regression equation:

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

where p_{it} denotes the logarithm of the price for the *i*-th market at time *t*, $\Delta p_{it} = p_{it} - p_{it-1}$, ρ are coefficients to be estimated, *q* is the number of lagged terms, *t* is the trend term, α_1 is the estimated coefficient for the trend, α_0 is the constant, and ε is white noise. MacKinnon's critical values are used in order to determine the significance of the test statistic associated with ρ_0. The PP incorporates an alternative (nonparametric) method of controlling for serial correlation when testing for a unit root by estimating the non-augmented Dickey-Fuller test equation and modifying the test statistic so that its asymptotic distribution is unaffected by serial correlation. Finally, the KPSS test differs from these other unit root tests in that the series is assumed to be stationary under the null.

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

4.4 Multiple variance ratio tests

The multiple variance ratio (MVR) test as proposed by Chow and Denning (1993) is used to detect autocorrelation and heteroskedasticity in the returns. Based on Lo and MacKinlay's (1988) 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 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 ($p_0, p_1, \ldots, p_{nq}$), 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 ($p_0, p_1, \ldots, p_{nq}$) 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 $SMM(\alpha;m;T)$ 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 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 then 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 $q = 2$:

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

5. 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 tests (pure random walk) 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 (random walk) is tested against the alternative of no unit root. For the latter, the null hypothesis of no unit root is tested against the alternative of a unit root (random walk).

<TABLE 2 HERE>

Turning first to the tests of independence, all of the null hypotheses of no serial correlation for the twenty-seven emerging markets are rejected at the .10 level or lower, with the exception of Egypt and Jordan. The null hypothesis of no serial correlation is rejected at the .10 level for Israel and the .05 level for Hungary and Argentina and at the .01 level

elsewhere. The significance of the autocorrelation coefficient indicates that the null hypothesis of weak-form market efficiency may be rejected and we may infer that twenty-five of the markets are weak-form inefficient over the various sample periods.

With the exception of Argentina, all of the significant coefficients are positive indicating persistence in returns, with persistence being higher in Columbia (0.3390), Sri Lanka (0.2640) and Chile (0.2270) and lower in Israel (0.0290), Hungary (0.0420) and Taiwan (0.0600). The average persistence is 0.1374 in these emerging 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 markets exhibiting persistence (mean-reversion) could also exhibit mean-reversion (persistence). In terms of the runs tests, the negative *z*-values for all of the markets 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, except Egypt. These likewise indicate positive serial correlation. We then also 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) used monthly data and runs tests to conclude that only the Philippines, Singapore, Taiwan and Thailand were not weak-form efficient from an international investor's perspective (when measured in US dollars) while Korea, Indonesia, Malaysia and Thailand were weak-form efficient on this basis. Poshakwale (1996) also rejected the null hypothesis of weak form efficiency using runs tests, though only for the Indian market.

The unit root tests in Table 2 are supportive of the hypothesis that most of these emerging equity markets are weak-form efficient. The ADF and PP *t*-statistics fail to reject the null hypotheses of a unit root at the .01 level or lower, thereby indicating that all of the return series examined are non-stationary (weak form efficient) with the exception of Mexico, Poland and Taiwan. For the KPSS tests of the null hypothesis of no unit root, the *LM*-statistic exceeds the asymptotic critical value at the .01 level for all emerging markets with the exception of Czech Republic, Poland and Taiwan. As a necessary condition for a random walk, the ADF and PP unit root tests fail to reject the requisite null hypothesis in the case of all twenty-four emerging markets except Mexico, Poland and Taiwan, while the KPSS unit root tests reject the required null in twenty-four emerging markets, with the exception of the Czech Republic, Poland and Taiwan. From the three unit root tests, the results indicate that a majority of emerging markets are weak-form efficient. However, since it is well know that unit root tests have very poor power properties, a preferred alternative is to use multiple variance ratio tests.

Table 3 presents the results of the multiple variance ratio tests of returns in the twenty-seven emerging equity 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 1,498 observations (Egypt) 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 India. The null hypothesis that daily equity returns follow a homoskedastic random walk is rejected at Z(2) = 7.0171. 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 Indian 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) = 5.2580. The heteroskedastic random walk hypothesis is thus rejected because of autocorrelation in the daily increments of the returns on Indian equity. We may conclude that the Indian 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 [India's serial correlation coefficient in Table 2 is 0.1340]. On this basis, the estimated first order autocorrelation coefficient is 0.1347 corresponding to the estimated variance ratio $V\hat{R}(2)$ of 1.1347 (i.e. 1.1347 - 1.0000). Further, persistence is suggested where $V\hat{R}(2) > 1$, whereas when $V\hat{R}(2) < 1$ a mean reverting process is indicated. This indicates there is positive autocorrelation (or persistence) in Indian equity returns over the long horizon.

By way of comparison, observe the results for Hungary. At none of the sampling intervals are the test statistics for the null hypotheses of homoskedastic, *Z(q)* and

heteroskedastic, $Z^*(q)$ random walks greater than the critical value of 2.49. This suggests that the Hungarian equity market is weak-form efficient. Alternatively, in the case of Egypt the null hypotheses of a homoskedastic random walk is rejected [$Z(q)$=2.6916], but the null hypothesis of heteroskedastic random walk is not [$Z^*(q)$=1.9862]. This indicates that rejection of the null hypothesis of a homoskedastic random walk could be the result, at least in part, of heteroskedasticity in the returns, and cannot be assigned exclusively to the autocorrelation in returns. This is especially important in the case of Egypt since the serial correlation and runs tests were both suggestive that returns in that market followed a random walk. In fact, it is likely that the apparent random walk was partly a product of heteroskedasticity in daily returns, and not the absence of autocorrelation.

Of the twenty-seven emerging markets, the multiple variance ratios testing procedure rejects the null hypothesis of a random walk under assumptions of both homoskedasticity and heteroskedasticity for all with the exception of Egypt, Korea, Malaysia, Hungary, Argentina, Israel and Jordan. We may then conclude that none of the former is weak-form efficient. With Egypt, Korea, Malaysia and Argentina the null hypothesis of a homoskedastic random walk is rejected, but not that for a heteroskedastic random walk. This infers that the random walk violation could be the result of heteroskedasticity and autocorrelation in daily returns. On this basis, there is strong evidence that Israel, Jordan and Hungary are weak-form efficient, while Egypt, Korea, Malaysia and Argentine have weaker evidence of weak-form efficiency. Nevertheless, the multiple variance ratio technique indicates the presence of positive autocorrelation (or persistence) in all these markets (except Argentina where negative autocorrelation or mean reversion is indicated) and thereby provides comparable evidence to the results of the serial correlation coefficients and runs tests. A summary of random walk test results is presented in Table 4.

<TABLE 4 HERE>

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

(2001) concluded that random walks could be rejected in all of China's stock exchanges on the basis of variance ratio tests.

A similar situation exists in previous work covering European emerging equity markets. Rockinger and Urga (2000: 471) used daily data and GARCH analysis to also conclude that of the markets considered (Czech Republic, Hungary, Poland and Russia) only "…the Hungarian market is nonpredictable over the entire sample and, therefore, satisfies our criteria for weak efficiency. This result is in line with the fact that this market has existed for 10 years longer than the other markets and is strongly regulated". Hajek (2002: 377) likewise found in a study of the Czech market that "results from serial correlation, Box-Pierce and Variance Ratio tests provide evidence that a random walk hypothesis cannot be validated with respect to the daily returns. The weak-form of efficiency on the Czech equity markets was thus not proved".

Finally, the results strongly contradict earlier evidence on market efficiency in Latin American emerging markets. Urrutia (1995) and Ojah and Karemera (1999), for instance, concluded that Argentina, Brazil, and Chile were weak-form efficient, though Urrutia (1995) and Karemera et al. (1999) surmised that Mexico was weak-form inefficient. They do, however, substantiate Haque et al. (2001) conclusion that all of these markets are not weak-form efficient on the basis of testing the earlier Lo and MacKinlay (1988) single variance ratio procedure using weekly returns.

6. CONCLUSION AND POLICY OUTCOMES

Financial development is an important determinant of an economy's ability to grow and develop over time. At the various national levels, the many types of financial regulatory reforms pursued and the different financial frameworks established come together, however the ability of these differently deregulated and liberalised markets to perform their role ultimately depends upon the level of market efficiency. In this manner, a quantitative knowledge of market efficiency allows the past progress in financial development to be assayed, and gives direction on suitable national benchmarks for policymakers and others in the future.

This paper examines the weak-form market efficiency of twenty-seven emerging equity markets. Three different procedures are employed to test for random walks in daily returns: (i) the parametric serial correlation coefficient and the nonparametric runs test are used to test for serial correlation; (ii) Augmented Dickey-Fuller, Phillips-Perron and

Kwiatkowski, Phillips, Schmidt and Shin unit root tests are used to test for non-stationarity as a necessary condition for a random walk; 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, categorically rejecting the presence of random walks in daily returns in most markets, with the exception of Egypt and Jordan, while the runs tests produce similar results, with the exception of Egypt. Contrary to the serial correlation and runs tests, the unit root tests conclude that unit roots, as necessary conditions for a random walk (weak-form market efficiency), are present in all, or nearly all, of the log of the price series, with the exception of Mexico, Poland and Taiwan for the ADF and PP tests and the Czech Republic, Poland and Taiwan for the KPSS test. Finally, the multiple variance ratio procedure conclusively rejects the presence of random walks in most emerging markets. Only Hungary, Jordan and Israel satisfy the most stringent random walk criteria with Egypt, Korea, Malaysia and Argentina meeting at most some of the requirements of a random walk.

The results of this analysis are consistent with the generalisation that emerging markets are unlikely to be associated with the random walks required for the assumption of weak-form market efficiency. This says that much progress is still needed in terms of financial development. Furthermore, the results offer contradictory evidence to earlier work using a variety of tests for random walks, of which the most likely contributory factor in those instances is the use of weekly and monthly sampling frequencies, rather than any variation in testing procedure.

The policy outcomes of this analysis are less certain. This is because while market efficiency has been measured, no attempt has been made to link this with market breadth, depth and liquidity or with the underlying pace of deregulation and liberalisation. However, depending upon the test employed, some markets are obviously more efficient than others and this provides useful benchmarks, both regionally and globally. Such benchmarks include Hungary in Europe, Egypt in Africa, Argentina in Latin America, Israel and Jordan in the Middle East and Malaysia and Korea in Asia. Closer examination of the developments in these markets is then warranted. One common feature is their relatively long tenure when compared to other emerging markets. This suggests that institutional maturity is an important determinant of market efficiency. These markets are also generally larger and this could also be linked with their efficiency.

There are, of course, a number of ways in which this research could be extended. One possible extension would be to use the multiple variance ratio test procedure in conjunctions with intraday data. While Ronen (1997) and Andersen et al. (2001) have shown that the single

variance ratio test is not robust and can be misleading in a high-frequency context, no such evidence concerns the more developed multiple variance ratio test. A second extension would be to examine more fully the relationship between the evolving characteristics of emerging stock markets and market efficiency. It is generally known that weak-form inefficiency is linked with the newer, small capitalisation markets with low levels of liquidity and turnover but little is known about how quickly markets approach a random walk as they become more liquid and institutionally mature. Stock level data may be able to throw some light on this question with the contrast between large and small capitalisation stocks, as would the decomposition of the data used in this analysis into shorter periods.

REFERENCES

Abraham, A., F.J. Seyyed, and S.A. Alsakran (2002), "Testing the random walk behaviour and efficiency of the Gulf stock markets," *The Financial Review*, Vol. 37, 469-480.

Andersen, T.G., T. Bollerslev, and A. Das (2001), "Variance ratio statistics and high-frequency data: Testing for changes in intraday volatility patterns," *Journal of Finance*, Vol. 56, 305-327.

Appiah-Kusi, J. and K. Menyah (2003), "Return predictability in African stock markets," *Review of Financial Economics*, Vol. 12. 247-271.

Ayadi, O.F. and C.S. Pyun (1994), "An application of variance ratio test to the Korean securities market," *Journal of Banking and Finance*, Vol. 18, 643-658.

Buguk, C. and B.W. Brorsen (2003), "Testing weak-form market efficiency: Evidence from the Istanbul stock exchange," *International Review of Financial Analysis* (in press).

Campbell, J.Y., A.W. Lo, and A.C. MacKinlay (1997), *The Econometrics of Financial Markets*, Princeton, Princeton University Press.

Cheung, K.C. and J.A. Coutts (2001), "A note on weak form market efficiency in security prices: Evidence from the Hong Kong stock exchange," *Applied Economics Letters*, Vol. 8, 407-410.

Chow. K.V. and K. Denning (1993), "A simple multiple variance ratio test," *Journal of Econometrics*, Vol. 58, 385-401.

Dezelan, S. (2000), "Efficiency of the Slovenian equity market," *Economic and Business Review*, Vol. 2, 61-83.

Fama, E. (1970), "Efficiency markets: A review of theory and empirical work," *Journal of Finance*, Vol. 25, 1181-1185.

Fama, E. (1991), "Efficient capital markets II," *Journal of Finance*, Vol. 46, 1575-1617.

Grieb, T. and M.G. Reyes (1999), "Random walk tests for Latin American equity indexes and individual firms," *Journal of Financial Research*, Vol. 22, 371-383.

Groenewold, N. and M. Ariff (1998), "The effects of de-regulation on share market efficiency in the Asia-Pacific," *International Economic Journal*, Vol.12, 23-47.

Groenewold, N. and K.C. Kang (1993), "The semi-strong efficiency of the Australian share market," *Economic Record*, Vol. 69, 405-410.

Hajek, J. (2002), "Weak-form efficiency in the Czech equity market," *Politicka Ekonomie*, Vol. 50, 377-389.

Haque, M., M.K. Hassan, and O. Varela (2001), "Stability, volatility, risk premiums and predictability in Latin American emerging stock markets," *Quarterly Journal of Business and Economics*, Vol. 40, 23-44.

Huang, B.N. (1995), "Do Asian stock markets follow random walks? Evidence from the variance ratio test," *Applied Financial Economics*, Vol. 5, 251-256.

Karemera, D., K. Ojah, and J.A. Cole (1999), "Random walks and market efficiency tests: Evidence from emerging equity markets," *Review of Quantitative Finance and Accounting*, Vol.13, 171-188.

Kawatsu, H. and M.R. Morey (1999), "An empirical examination of financial liberalization and the efficiency of emerging market stock prices," *Journal of Financial Research*, Vol. 22, 385-411.

Lee, C.F., G.M. Chen, and O.M. Rui (2001), "Stock returns and volatility on China's stock markets," *Journal of Financial Research*, Vol. 24, 523-543.

Lian, K.K. and G.K. Leng (1994), "Weak-form efficiency and mean reversion in the Malaysian stock market," *Asia-Pacific Development Journal*, Vol. 1, 137-152.

Lo, A. and A.C. MacKinlay (1988), "Stock market prices do not follow random walks: Evidence from a simple specification test," *Review of Financial Studies*, Vol. 1, 41-66.

Los, C.A. (2000), "Nonparametric efficiency testing of Asian stock markets using weekly data," chapter in *Advances in Econometrics Vol. 14*, Stanford, Conn.: JAI Press.

Ojah, K. and D. Karemera (1999), "Random walks and market efficiency tests of Latin American Emerging equity markets: A revisit," *The Financial Review*, Vol. 34, 57-72.

Poon, S.H. (1996), "Persistence and mean reversion in UK stock returns," *European Financial Management*, Vol. 2, 169-196.

Poshakwale, S. (1996), "Evidence on weak form efficiency and day-of-the-week effect in the Indian stock market," *Finance India*, Vol. 10, 605-616.

Regúlez, M. and A. Zarraga (2002), "Common features between stock returns and trading volume," *Applied Financial Economics*, Vol.12, 885-893.

Rockinger, M. and G. Urga (2000), "The evolution of stock markets in transition economies," *Journal of Comparative Economics*, Vol. 28, 456-472.

Ronen, T. (1997), "Tests and properties of variance ratios in microstructure studies," *Journal of Financial and Quantitative Analysis*, Vol. 32, 183-204.

Ryoo, H.J. and G. Smith (2002), "Korean stock prices under price limits: Variance ratio tests of random walks," *Applied Financial Economics*, Vol.12, 545-553.

Smith, G., K. Jefferis, and H.J. Ryoo (2002), "African stock markets: multiple variance ratio tests of random walks," *Applied Financial Economics*, Vol. 12, 475-484.

Urrutia, J.L. (1995), "Tests of random walk and market efficiency for Latin American emerging markets," *Journal of Financial Research*, Vol.18, 299-309.

Zychowicz, E.J., M. Binbasioglu, and N. Kazancioglu (1995), "The behaviour of prices on the Istanbul stock exchange," *Journal of International Financial Markets, Institutions and Money*, Vol. 5, 61-71.

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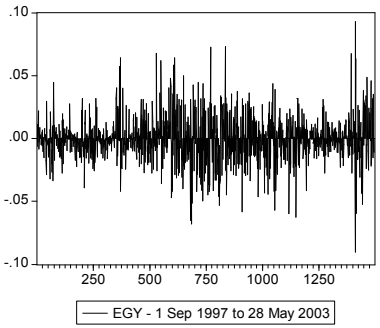
Table 1. Descriptive Statistics for Emerging Capital Markets

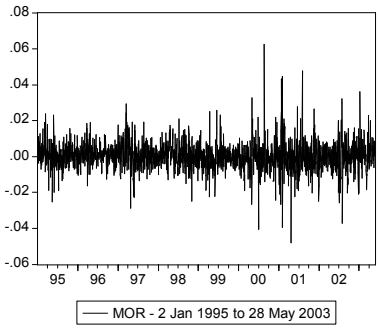
	Market	Start	End	Observations	Mean	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	JB *p*-value
Africa	EGY	01-Sep-1997	28-May-2003	1498	-6.43E-04	0.0929	-0.0900	0.0163	0.1948	6.9287	9.73E+02	0.0000
	MOR	02-Jan-1995	28-May-2003	2192	1.74E-04	0.0625	-0.0482	0.0077	0.3841	9.1153	3.47E+03	0.0000
	SAF	01-Jan-1993	28-May-2003	2714	1.53E-04	0.1126	-0.1302	0.0155	-0.3884	9.8804	5.42E+03	0.0000
Asia	CHN	31-Dec-1992	28-May-2003	2714	-6.92E-04	0.1274	-0.1444	0.0206	0.1499	7.8377	2.66E+03	0.0000
	IND	31-Dec-1992	28-May-2003	2714	-5.51E-05	0.0886	-0.0896	0.0160	-0.1047	5.9132	9.65E+02	0.0000
	INA	31-Dec-1987	28-May-2003	4019	4.63E-05	0.4451	-0.4308	0.0287	0.1186	46.3110	3.14E+05	0.0000
	KOR	31-Dec-1987	28-May-2003	4019	4.10E-05	0.2688	-0.2167	0.0238	0.3767	15.3820	2.58E+04	0.0000
	MLY	31-Dec-1987	28-May-2003	4019	1.19E-04	0.2585	-0.3697	0.0196	-0.7903	60.5769	5.56E+05	0.0000
	PAK	1-Nov-1995	28-May-2003	1975	-1.82E-04	0.1421	-0.1573	0.0218	-0.4492	9.3993	3.44E+03	0.0000
	PHL	31-Dec-1987	28-May-2003	4019	-4.53E-05	0.2197	-0.1094	0.0174	0.7072	15.8291	2.79E+04	0.0000
	SRI	31-Dec-1992	28-May-2003	2714	-1.34E-04	0.2758	-0.1014	0.0149	2.5955	50.4735	2.58E+05	0.0000
	TWN	31-Dec-1987	28-May-2003	4019	1.14E-04	0.1265	-0.1113	0.0213	0.0214	5.3354	9.14E+02	0.0000
	THA	31-Dec-1987	28-May-2003	4019	-2.61E-05	0.1810	-0.1444	0.0216	0.6936	12.3500	1.50E+04	0.0000
Europe	CZH	30-Dec-1994	28-May-2003	2193	1.60E-04	0.0676	-0.0739	0.0155	-0.1012	5.0435	3.85E+02	0.0000
	HGY	30-Dec-1994	28-May-2003	2193	5.28E-04	0.3796	-0.2580	0.0218	2.6035	71.5944	4.32E+05	0.0000
	POL	31-Dec-1992	28-May-2003	2714	4.82E-04	0.1253	-0.1159	0.0242	-0.1407	6.7288	1.58E+03	0.0000
	RUS	2-Jan-1995	28-May-2003	2193	5.80E-04	0.2422	-0.3101	0.0360	-0.3899	11.3524	6.43E+03	0.0000
Latin America	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
Middle East	ISR	01-Jan-1993	28-May-2003	2714	6.75E-05	0.0828	-0.0979	0.0165	-0.2436	6.7389	1.61E+03	0.0000
	JOR	01-Jan-1998	28-May-2003	4019	-4.79E-05	0.0890	-0.3391	0.0104	-9.4699	309.6680	1.58E+07	0.0000
	TUR	01-Jan-1998	28-May-2003	4019	5.65E-05	0.2201	-0.2742	0.0340	-0.1229	7.7714	3.82E+03	0.0000

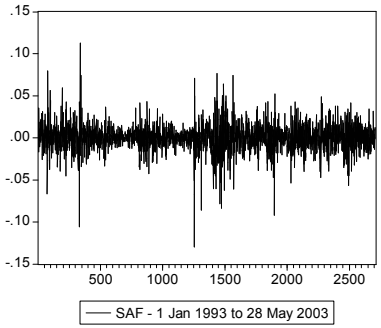
Notes: Africa: EGY – Egypt, MOR – Morocco, SAF – South Africa; Asia: CHN – China, IND – India, INA – Indonesia, KOR – Korea, MLY – Malaysia, PAK – Pakistan, PHL – Philippines, SRI – Sri Lanka, TWN – Taiwan, THA – Thailand; Europe: CZH – Czech Republic, HGY – Hungary, POL – Poland, RUS – Russia; Latin America: ARG – Argentina, BRZ – Brazil, CHL – Chile, COL – Columbia, MEX – Mexico, PRU – Peru, VEN – Venezuela; Middle East: ISR – Israel, JOR – Jordan, TUR – Turkey. JB – Jarque-Bera. Critical values for significance of skewness and kurtosis respectively at the .05 level are 0.1240 and 0.2481 (EGY), 0.1080 and 0.2161 (PAK), 0.1025 and 0.2051 (MOR, CZH, HGY, RUS), 0.0922 and 0.1843 (SAF, CHN, IND, SRI, POL, COL, PRU, VEN, ISR), 0.0757 and 0.1515 (INA, KOR, MLY, PHL, TWN, THA, ARG, BRZ, CHL, MEX, JOR, TUR).

Figure 1. Daily Returns for Emerging Capital Markets

Africa







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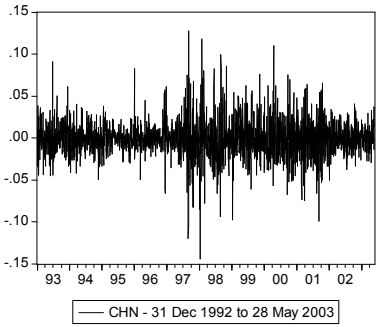
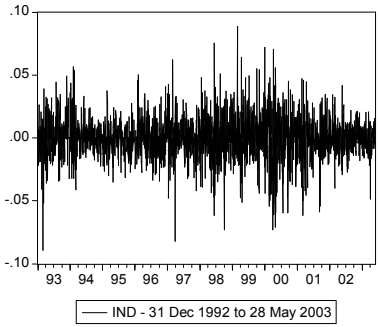
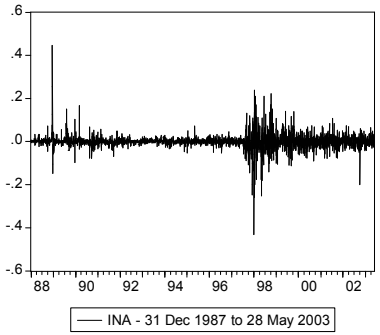
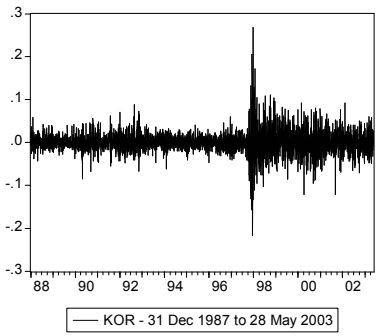
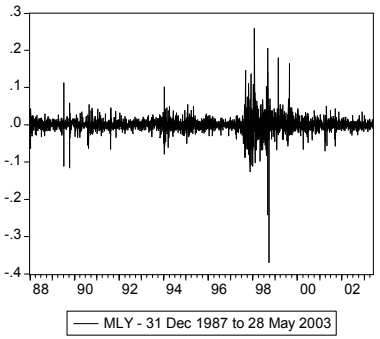
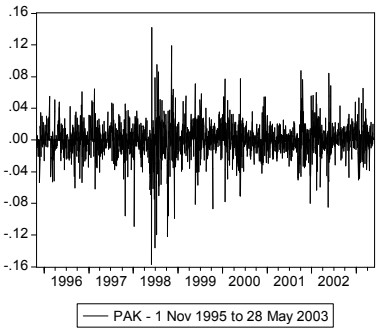


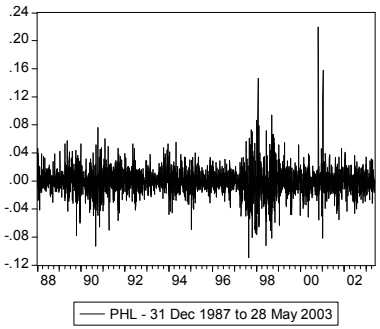


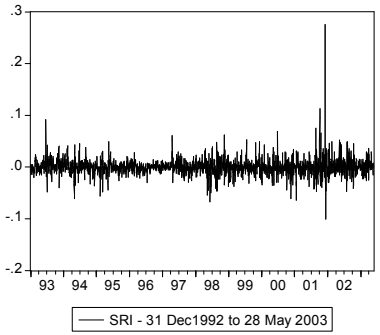


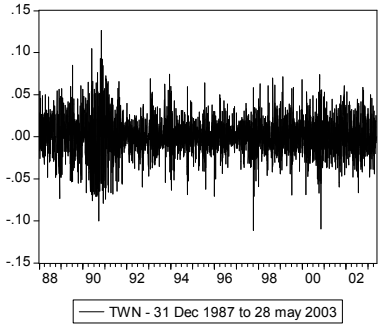


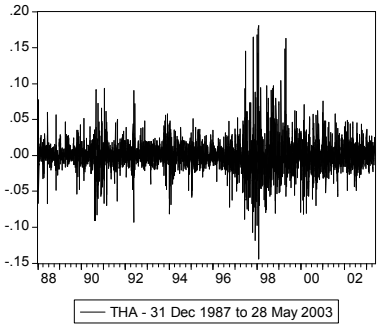




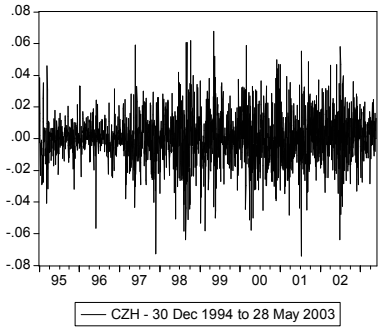


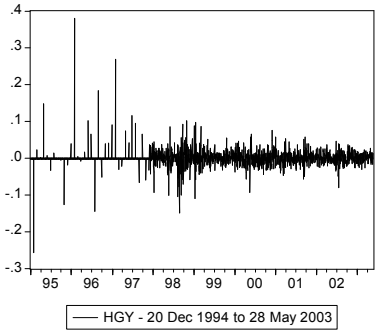


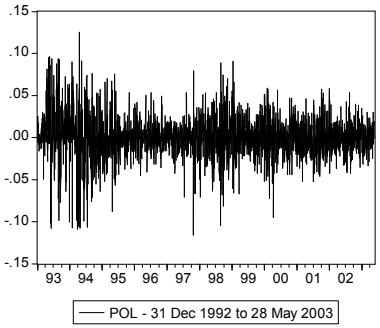


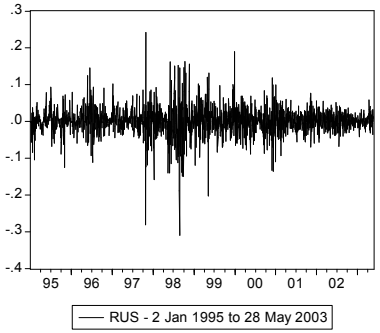


Europe

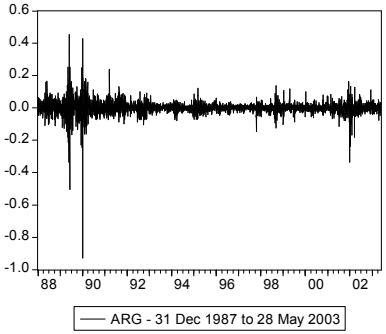


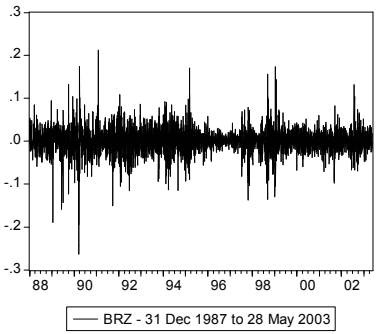


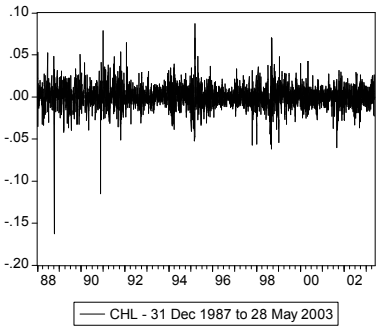


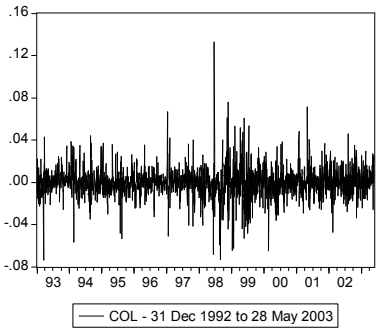


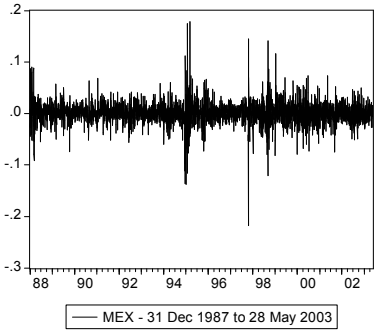
Latin America

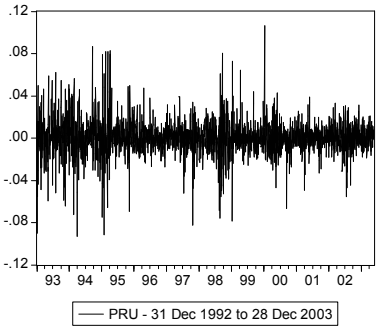


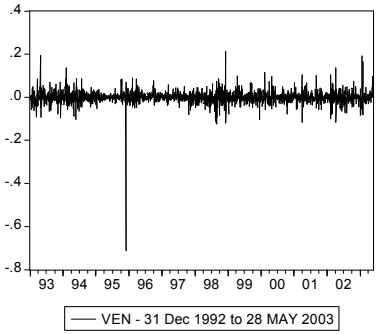




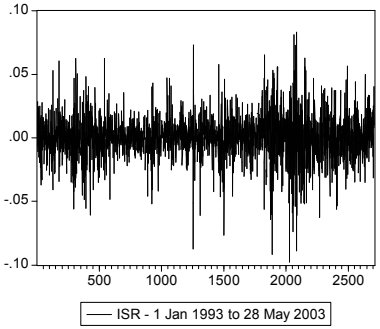


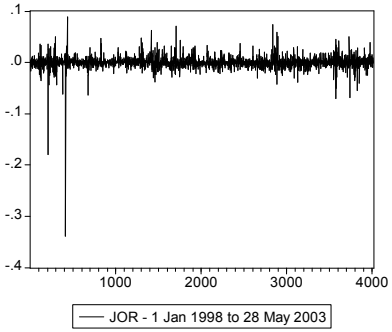

MEX - 31 Dec 1987 to 28 May 2003


PRU - 31 Dec 1992 to 28 Dec 2003


VEN - 31 Dec 1992 to 28 MAY 2003

Middle East


ISR - 1 Jan 1993 to 28 May 2003


JOR - 1 Jan 1998 to 28 May 2003

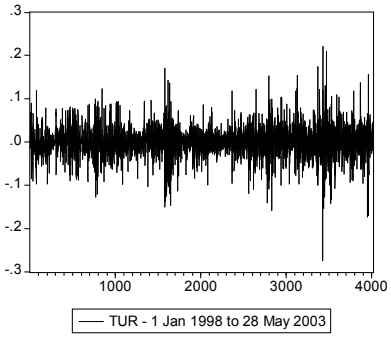

TUR - 1 Jan 1998 to 28 May 2003

Table 2. Independence and Unit Root Tests for Emerging Capital 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
Africa	EGY	0.0210	0.2083	-6.43E-04	631	867	1498	704	-1.4529	0.1462	-0.9003	0.7886	-0.9066	0.7866	3.6860	0.0100
	MOR	0.1410	0.0000	1.74E-04	1127	1066	2193	1023	-3.1487	0.0016	-1.6989	0.4317	-1.6817	0.4405	1.4754	0.0100
	SAF	0.0900	0.0000	1.63E-04	1357	1357	2714	1235	-4.7229	0.0000	-2.5872	0.0957	-2.5750	0.0983	1.5328	0.0100
Asia	CHN	0.1800	0.0000	-6.92E-04	1348	1366	2714	1181	-6.7944	0.0000	-0.8120	0.8151	-0.7555	0.8306	5.9522	0.0100
	IND	0.1340	0.0000	-5.51E-05	1302	1412	2714	1147	-8.0295	0.0000	-2.1261	0.2344	-2.0892	0.2492	0.9207	0.0100
	INA	0.1850	0.0000	4.63E-05	2064	1955	4019	1745	-8.3365	0.0000	-1.3241	0.6205	-1.3887	0.5894	3.8200	0.0100
	KOR	0.0730	0.0000	4.10E-05	2171	1848	4019	1837	-5.0977	0.0000	-2.1096	0.2410	-2.1864	0.2114	1.4078	0.0100
	MLY	0.0920	0.0000	1.19E-04	2040	1979	4019	1763	-7.7963	0.0000	-1.8086	0.3767	-1.9145	0.3258	1.0652	0.0100
	PAK	0.0700	0.0009	-1.82E-04	869	1106	1975	906	-3.1185	0.0018	-1.6106	0.4769	-1.7596	0.4010	3.0615	0.0100
	PHL	0.1790	0.0000	-4.53E-05	1940	2079	4019	1777	-7.3003	0.0000	-0.8497	0.8042	-0.8561	0.8023	1.7749	0.0100
	SRI	0.2640	0.0000	-1.34E-04	1292	1422	2714	1079	-10.6178	0.0000	-1.0677	0.7305	-1.1639	0.6921	5.0127	0.0100
	TWN	0.0600	0.0001	1.14E-04	2139	1880	4019	1911	-2.8881	0.0039	-2.9705	0.0378	-3.0367	0.0317	0.4037	–
	THA	0.1840	0.0000	-2.61E-05	1958	2061	4019	1767	-7.6463	0.0000	-1.0626	0.7325	-0.9995	0.7556	3.6711	0.0100
Europe	CZH	0.1200	0.0000	1.60E-04	1092	1101	2193	987	-4.7196	0.0000	-1.5711	0.4973	-1.4422	0.5628	0.4740	–
	HGY	0.0420	0.0246	5.28E-04	1453	740	2193	731	-11.9708	0.0000	-1.5549	0.5056	-1.5627	0.5016	2.8771	0.0100
	POL	0.1430	0.0000	4.82E-04	1411	1303	2714	1255	-3.8786	0.0001	-4.0981	0.0010	-4.0842	0.0010	0.4490	–
	RUS	0.0930	0.0000	5.80E-04	1113	1079	2192	957	-5.9720	0.0000	-1.4691	0.5493	-1.5553	0.5054	1.5524	0.0100
Latin America	ARG	-0.0310	0.0247	4.52E-04	2106	1913	4019	1867	-4.3916	0.0000	-2.6501	0.0831	-2.6549	0.0822	3.1939	0.0100
	BRZ	0.1520	0.0000	3.98E-04	2054	1965	4019	1791	-6.8979	0.0000	-2.4406	0.1307	-2.4976	0.1161	5.0290	0.0100
	CHL	0.2270	0.0000	4.19E-04	2126	1893	4019	1585	-13.2568	0.0000	-2.6332	0.0863	-2.5961	0.0938	4.1724	0.0100
	COL	0.3390	0.0000	-8.87E-05	1315	1399	2714	1043	-12.0569	0.0000	-1.1330	0.7048	-1.2526	0.6535	4.2617	0.0100
	MEX	0.1230	0.0000	6.87E-04	2074	1945	4019	1775	-7.3727	0.0000	-3.2238	0.0187	-3.2635	0.0167	4.7819	0.0100
	PRU	0.1810	0.0000	2.69E-04	1404	1310	2714	1245	-4.2816	0.0000	-2.2022	0.2057	-2.1284	0.2335	1.0369	0.0100
	VEN	0.0930	0.0000	8.45E-06	1454	1260	2714	1185	-6.4093	0.0000	-2.7039	0.0734	-2.5935	0.0944	0.7922	0.0100
Middle East	ISR	0.0290	0.0655	1.30E-04	1357	1357	2714	1276	-3.1486	0.0016	-1.6349	0.4645	-1.6961	0.4332	2.2301	0.0100
	JOR	-0.0090	0.2842	-4.79E-05	1473	2546	4019	1695	-5.8525	0.0000	-1.9622	0.3039	-1.9779	0.2968	0.8947	0.0100
	TUR	0.1030	0.0000	5.65E-05	2092	1927	4019	1799	-6.5774	0.0000	-2.2665	0.1831	-2.2930	0.1743	1.4955	0.0100

Notes: Africa: EGY – Egypt, MOR – Morocco, SAF – South Africa; Asia: CHN – China, IND – India, INA – Indonesia, KOR – Korea, MLY – Malaysia, PAK – Pakistan, PHL – Philippines, SRI – Sri Lanka, TWN – Taiwan, THA – Thailand; Europe: CZH – Czech Republic, HGY – Hungary, POL – Poland, RUS – Russia; Latin America: ARG – Argentina, BRZ – Brazil, CHL – Chile, COL – Columbia, MEX – Mexico, PRU – Peru, VEN – Venezuela; Middle East: ISR – Israel, JOR – Jordan, TUR – Turkey. 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. Pure random walk 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 Emerging Capital Markets

Market	Statistics	q = 2	q = 5	q = 10	q = 20	Market	Statistics	q = 2	q = 5	q = 10	q = 20	Market	Statistics	q = 2	q = 5	q = 10	q = 20
EGY	VRq	1.0220	1.1524	1.1940	1.2429	PHL	VRq	1.1816	1.3061	1.3347	1.5881	BRZ	VRq	1.1530	1.3386	1.4444	1.5376
	Zq	0.8515	*2.6916	2.2244	1.8915		Zq	*11.5136	8.8576	6.2843	7.5022		Zq	9.6965	*9.7974	8.3445	6.8571
	Z*q	0.6255	1.9862	1.6646	1.4923		Z*q	*6.1956	5.1894	3.9776	5.0838		Z*q	5.0969	*5.3539	4.9252	4.3488
MOR	VRq	1.1458	1.4130	1.6097	1.8559	SRI	VRq	1.2646	1.5524	1.8235	2.0574	CHL	VRq	1.2299	1.3986	1.5281	1.7725
	Zq	6.8295	8.8272	*8.4570	8.0644		Zq	*13.7825	13.1355	12.7055	11.0840		Zq	*14.5756	11.5350	9.9155	9.8541
	Z*q	4.3886	6.2088	6.2832	*6.2868		Z*q	6.8487	*7.0220	6.8004	6.5137		Z*q	*9.4875	7.7593	7.0012	7.4213
SAF	VRq	1.0917	1.1729	1.1962	1.2640	TWN	VRq	1.0614	1.1812	1.2226	1.3759	COL	VRq	1.3402	1.8039	2.0702	2.4869
	Zq	*4.7789	4.1118	3.0275	2.7669		Zq	3.8896	*5.2418	4.1790	4.7952		Zq	17.7205	*19.1145	16.5124	15.5860
	Z*q	*2.8062	2.6131	2.0168	1.9497		Z*q	2.9760	*3.8226	3.0566	3.5432		Z*q	10.1606	*11.9481	11.0265	11.0981
CHN	VRq	1.1805	1.3272	1.3081	1.4551	THA	VRq	1.1849	1.3216	1.3007	1.4653	MEX	VRq	1.1244	1.1939	1.2105	1.3425
	Zq	*9.4053	7.7807	4.7532	4.7705		Zq	*11.7214	9.3069	5.6452	5.9350		Zq	*7.8833	5.6113	3.9516	4.3690
	Z*q	*5.5254	4.8829	3.1739	3.3900		Z*q	*6.3203	5.0496	3.2070	3.5353		Z*q	*3.6223	2.8368	2.1745	2.5795
IND	VRq	1.1347	1.2674	1.3008	1.4189	CZH	VRq	1.1221	1.1910	1.1723	1.3414	PRU	VRq	1.1818	1.2814	1.2651	1.3679
	Zq	*7.0171	6.3577	4.6420	4.3912		Zq	*5.7185	4.0822	2.3902	3.2165		Zq	*9.4709	6.6907	4.0902	3.8568
	Z*q	*5.2580	4.7768	3.5559	3.4763		Z*q	*4.6378	3.2832	1.9160	2.6147		Z*q	*5.8074	4.3022	2.7807	2.7895
INA	VRq	1.1863	1.3268	1.2810	1.4412	HGY	VRq	1.0427	1.0437	1.0233	1.1223	VEN	VRq	1.1342	1.1300	1.1495	1.1610
	Zq	*11.8110	9.4556	5.2762	5.6282		Zq	1.9987	0.9331	0.3228	1.1520		Zq	*6.9890	3.0900	2.3061	1.6876
	Z*q	*3.2535	2.9189	1.7275	2.0253		Z*q	1.9141	0.9187	0.3273	1.1975		Z*q	*4.0589	1.8932	1.5833	1.2960
KOR	VRq	1.0740	1.0164	0.9255	1.0246	POL	VRq	1.1452	1.3358	1.4047	1.6208	ISR	VRq	1.0301	1.0862	1.0760	1.1142
	Zq	*4.6891	0.4738	-1.3979	0.3136		Zq	7.5629	*7.9845	6.2440	6.5076		Zq	1.5663	2.0507	1.1724	1.1975
	Z*q	2.3758	0.2243	-0.6490	0.1474		Z*q	5.2307	*5.3495	4.2133	4.5407		Z*q	1.0966	1.4564	0.8604	0.9065
MLY	VRq	1.0929	1.1896	1.1459	1.1864	RUS	VRq	1.0939	1.2094	1.2882	1.4989	JOR	VRq	0.9915	0.9974	1.0197	1.0416
	Zq	*5.8880	5.4877	2.7393	2.3779		Zq	4.3948	*4.4755	3.9960	4.6997		Zq	-0.5376	-0.0756	0.3702	0.5310
	Z*q	1.8517	1.9006	1.0602	1.0158		Z*q	1.9353	2.3035	2.3310	*2.9737		Z*q	-0.3659	-0.0541	0.2730	0.3966
PAK	VRq	1.0717	1.2034	1.3401	1.5342	ARG	VRq	0.9698	0.8321	0.7445	0.7630	TUR	VRq	1.1031	1.1511	1.1964	1.3430
	Zq	3.1850	4.1249	4.4767	*4.7767		Zq	-1.9147	*-4.8571	-4.7980	-3.0226		Zq	*6.5369	4.3720	3.6871	4.3755
	Z*q	2.2264	2.7516	3.0597	*3.3991		Z*q	-0.6659	-1.4829	-1.5782	-1.0872		Z*q	*3.6577	2.5756	2.3516	3.0378

Notes: Africa: EGY – Egypt, MOR – Morocco, SAF – South Africa; Asia: CHN – China, IND – India, INA – Indonesia, KOR – Korea, MLY – Malaysia, PAK – Pakistan, PHL – Philippines, SRI – Sri Lanka, TWN – Taiwan, THA – Thailand; Europe: CZH – Czech Republic, HGY – Hungary, POL – Poland, RUS – Russia; Latin America: ARG – Argentina, BRZ – Brazil, CHL – Chile, COL – Columbia, MEX – Mexico, PRU – Peru, VEN – Venezuela; Middle East: ISR – Israel, JOR – Jordan, TUR – Turkey. VR(q) – variance ratio estimate, Z(q) - test statistic for null hypothesis of homoskedastic increments random walk, Z*(q) - test statistic for null hypothesis of heteroskedastic increments random walk; the critical value for Z(q) and Z*(q) at the 5 percent level of significance is 2.49, an asterisk indicates significance at this level; Sampling intervals (q) are in days.

Table 4. Summary Efficiency Outcomes

	Market	Serial correlation	Runs	ADF unit root	PP unit root	KPSS unit root	Multiple variance ratio
Africa	EGY	Efficient	Efficient	Efficient	Efficient	Efficient	Weakly efficient
	MOR	Inefficient	Inefficient	Efficient	Efficient	Efficient	Inefficient
	SAF	Inefficient	Inefficient	Efficient	Efficient	Efficient	Inefficient
Asia	CHN	Inefficient	Inefficient	Efficient	Efficient	Efficient	Inefficient
	IND	Inefficient	Inefficient	Efficient	Efficient	Efficient	Inefficient
	INA	Inefficient	Inefficient	Efficient	Efficient	Efficient	Inefficient
	KOR	Inefficient	Inefficient	Efficient	Efficient	Efficient	Weakly efficient
	MLY	Inefficient	Inefficient	Efficient	Efficient	Efficient	Weakly efficient
	PAK	Inefficient	Inefficient	Efficient	Efficient	Efficient	Inefficient
	PHL	Inefficient	Inefficient	Efficient	Efficient	Efficient	Inefficient
	SRI	Inefficient	Inefficient	Efficient	Efficient	Efficient	Inefficient
	TWN	Inefficient	Inefficient	Inefficient	Inefficient	Inefficient	Inefficient
	THA	Inefficient	Inefficient	Efficient	Efficient	Efficient	Inefficient
Europe	CZH	Inefficient	Inefficient	Efficient	Efficient	Inefficient	Inefficient
	HGY	Inefficient	Inefficient	Efficient	Efficient	Efficient	Strongly efficient
	POL	Inefficient	Inefficient	Inefficient	Inefficient	Inefficient	Inefficient
	RUS	Inefficient	Inefficient	Efficient	Efficient	Efficient	Inefficient
Latin America	ARG	Inefficient	Inefficient	Efficient	Efficient	Efficient	Weakly efficient
	BRZ	Inefficient	Inefficient	Efficient	Efficient	Efficient	Inefficient
	CHL	Inefficient	Inefficient	Efficient	Efficient	Efficient	Inefficient
	COL	Inefficient	Inefficient	Efficient	Efficient	Efficient	Inefficient
	MEX	Inefficient	Inefficient	Inefficient	Inefficient	Efficient	Inefficient
	PRU	Inefficient	Inefficient	Efficient	Efficient	Efficient	Inefficient
	VEN	Inefficient	Inefficient	Efficient	Efficient	Efficient	Inefficient
Middle East	ISR	Inefficient	Inefficient	Efficient	Efficient	Efficient	Strongly efficient
	JOR	Efficient	Inefficient	Efficient	Efficient	Efficient	Strongly efficient
	TUR	Inefficient	Inefficient	Efficient	Efficient	Efficient	Inefficient