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This study seeks evidence on whether the return series on Bangladesh's Dhaka Stock Exchange (DSE) is independent and follows the random walk model. The study focuses on assessing if the DSE deviates from idealised efficiency. The sample primarily includes all the listed companies on the DSE daily price index over the period 1988 to 2000. The results of both non-parametric (Kolmogrov—Smirnov: normality test and run test) and parametric test (Auto-correlation test, Auto-regressive model, ARIMA model) provide evidence that the security returns do not follow the random walk model and the significant auto-correlation coefficient at different lags reject the null hypothesis of weak-form efficiency. The results are consistent with observations in different sub-samples without outlier and for individual securities. This anomaly with the efficient market hypothesis supports the thought that the market does not respond to new information instantaneously. This may be due to a delay in dissemination to new price sensitive information or biases (under or over reaction) in the response of market participants to such information. It may also be for the momentum effect related to herding in particular 'positive feed back trading' or 'trend following' the trading strategy by the average investors.

JEL Classification: G12, G14, G34
Keywords: Weak-form market efficiency; emerging markets, stock market, information

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1. Introduction

Are security prices predictable? Can there be investors with information that is not reflected in security prices? Does information flow in multiple markets simultaneously? Do all investors have the same ability to acquire, process and disseminate information? Current literature is clearly divided on these questions. One school of thought believes that the market is efficient. Another school of thought believes that the financial markets are not efficient. Even within the believers of market efficiency, three forms of efficient market hypothesis are developed. A market is weak form efficient if the current stock prices or return series are not predictable from past prices or return information (Fama 1991). The market is semi-strong form efficient if the current security prices reflect all publicly available information. Finally, the market is strong form efficient if security prices reflect all private and public information.

There is a substantial body of literature on security pricing and theories explaining market and stock return behaviour in the developed market. However, most of the research is concentrated in the developed stock markets, particularly the US market. But the need for more research in the emerging and less developed markets is well recognised. The Dhaka Stock Exchange of Bangladesh, henceforth known as DSE, is one of the representatives of an emerging market during the period with rapid growth in terms of market capitalisation, trade volume and the number of listed companies. The lack of research in the Bangladeshi Stock Market, where the stock exchange has largely developed after the 1980s, the structure, functioning, efficiency and determinants of share returns are research questions which need to be addressed. In Bangladesh, the pace of industrialisation has suffered in the past due to factors like its being agricultural based country, lack of entrepreneurs, low level of productivity and lack of discipline in the financial sector. However, with the spree of privatisation and the success of stock markets in many of the South Asian Newly Industrialised Countries (NICs), Bangladesh presents an optimistic ground for effectively developing and utilising the capital market for industrial financing. With respect to the securities market in Bangladesh, foreign and national experts have undertaken some studies (for example, Robbins 1980, Tandon 1990 and Seok and Park 1992). All these studies mainly focus on the supply side problems of the securities market and suggest remedies for the improvement of the market.

The Dhaka stock market has been experiencing volatility since its inception—the indices reached the highest point in its history in November 1996 and eventually crashed; afterwards investors lost confidence in the market. As a result, regulators reformed the market and introduced automation in 1998 and this was expected to conduct studies on informational efficiency, particularly to investigate any improvement as a result of the automated trading system in the market. But there is no initiative put in place before this study to undertake research on the market efficiency issues afterwards.

The rest of this paper is structured as follows: Section 2 reviews the previous empirical evidence on weak-form efficiency; Section 3 discusses the sample and methodology; section 4 lays out the empirical results of this study. Finally Section 5 gives a summary and provides the conclusions.

2. Review of Literature

The evidence on weak-form efficiency is controversial especially in emerging markets. Studies like Sharma and Kennedy (1977) show weak-form efficiency in the Bombay Stock Exchange similar to that in the London Stock Exchange and the New York Stock Exchange but Roux and Gilbertson (1978) show weak-form inefficiency in the Johannesburg Stock Exchange/ Ghandi et al. (1980) too show similar findings about the Kuwaiti stock market. So, remarkable studies by Errunza and Losq (1985) support the hypothesis that markets in the less developed countries were quite comparable to European small markets and were not as efficient as the markets in developed countries. Branes (1986) experienced weak-form market efficiency in the Kuala Lumpur Stock Exchange despite the problem of thin trading. At the same time the findings of Laurence (1986) deviate a bit on the Kuala Lumpur and Singapore Stock Exchanges.

In addition, Chan et al. (1992) attempted to examine the integration among emerging markets in view of the globalisation of stock markets and evidenced that the stock prices in major Asian markets and in the US market were weak-form efficient individually and collectively in the long run while at the same time Butler and Malaikah (1992) examined efficiency and inefficiency in two thinly traded stock markets in the Middle East and noted that individual stocks in the Kuwaiti market were similar to other thinly traded markets exhibiting statistically significant auto-correlation whereas all stocks (sample) of the Saudi market showed a significant departure from random walk. Similarly, Cheung et al. (1993) reported inefficiency in the stock markets of Korea and Taiwan. Whereas, Dickinson and Muragu (1994) provide evidence consistent with the market efficiency on the Nairobi Stock Exchange. They conclude that small market such as the Nairobi Stock Exchange (provided a low serial correlation of stock returns) was weak-form efficient. Contrary to this, Urrutia (1995) rejected the weak-form efficiency in four Latin American emerging markets although his findings were not consistent between the two tests he used.

In short, most of the studies conducted in the less developed markets show the existence of weak-form inefficiency. For example, in a World Bank study Claessens et al. (1995) reported significant serial correlation in equity returns from 19 emerging markets and suggested that stock prices in emerging markets violate weak-form efficient market hypothesis (EMH). Similar findings were reported by Harvey (1994) for most emerging markets. Similarly, Poshakwale (1996, 1997) found that the Indian market was not weak-form efficient. Moreover, Khababa (1998) examined the behaviour of stock prices in the Saudi financial market seeking evidence for weak-form efficiency and suggested that the market was not weak-form efficient. On the other hand, Ojah and Karemera (1999) found weak-form efficiency in four emerging markets in Latin America except Chile. So, the findings from emerging markets are controversial. However, the findings of less developed markets are also interpreted in different ways. Market inefficiency results from barriers to the dissemination of information. It depends positively on the real cost of capital to speculators and negatively on the speed of information dissemination (Errunza and Losq 1985). Similarly, Khababa (1998) explains that the inefficiency in the Saudi financial market might be due to a delay in operations and high transaction costs, thinness of trading and illiquidity in the market. On the other hand, Dickinson and Muragu (1994) who did find evidence supporting the weak-form efficiency on the Nairobi Stock Exchange explain that in spite of the thinness of the market, information was disseminated because of sophisticated communication techniques through business journals and other media.

A few research works, conducted on stock returns in emerging and less developed markets are characterised by high volatility and predictability (Harvey 1994). Besides, Bakaert et al. (1996) also present evidence that the distribution of emerging equity market return is potentially unstable and differ in the 1990s than in the 1980s. Later Bekaert et al. (1997) state that research in emerging markets suggests high volatility and low correlation both across the emerging markets and with the developed markets. However, according to Shleifer (2000) the key forces by which markets are supposed to attain efficiency such as arbitrage and investors' rationality is contradicted with the psychological and institutional evidence in the real world. For instance, arbitrage is limited as it relies crucially on the availability of close substitutes. However, he introduces 'behavioural finance' as an alternative view of the financial markets. According to this new view, economic theory does not lead us to expect financial markets to be efficient. Rather, systematic and significant deviations from efficiency are expected to persist for longer periods of time.

Overall, the research findings on markets in developing and less developed countries are controversial. Based on the mixed results emerging market equities require more research and clarification. However, it is anticipated that the Dhaka stock market is not efficient at the highest degree. This paper as a pioneer test in this type, started from the lower category of efficiency that is testing the weak-form efficiency of the market. In addition, usually research on informational efficiency issues in emerging market prioritises testing weak-form market efficiency. Accordingly, this study mainly seeks evidence on whether the Bangladesh stock market return series is independent or follows the random walk model. Hence, it is an interesting empirical question whether and to what extent a less developed market like the Dhaka stock market is efficient and what return generation factors drive the market.

3. Data and Methodology

The empirical analysis in this study uses daily market return on the Dhaka Stock Exchange for the period 1988–2000. This sample period considered for the research is justified because this study period captures all major economic events like data availability since 1988, the market boom and the situations of both pre- and post-reforms. This study employs all share price indices daily time series data. The data of daily price indices and daily share prices of individual companies are mainly collected from the data channel (data stream) for the sample period of 1993 to 2000. Those data, which are not available on the data stream for the period 1988 to 1992, are collected from the daily price quotations officially published by the DSE. The non-availability of computerised databases has had a significantly limiting effect on market studies in developing countries, and consequently on the volume of published evidence (Dickinson and Muragu 1994). One probable solution to this problem is to use the indices of the index, which are available (see for example, Sharma and Kennedy 1977 and Ghandi et al. 1980). This study considers all daily share price indices on the DSE.[1] Given the unavailability of necessary data to construct a value weighted index, an equally weighted 'all share index' is used in the present study. It is important to note that although Bangladesh has been included in the IFC database since 1995, the whole sample period data is not available yet. However, to avoid the problem of thin trading bias of equally weighted indices, the study also considers 30 randomly selected actively traded individual companies return data only in the run test, which is the most direct test of weak-form efficiency.

The statistical techniques are applied by numerous researchers in testing weak-form efficiency can broadly be categorised into two: one is technical analysis and the other is the predictability of returns. The former approach is mainly concerned with using technical trading rules and examines whether they can be exploited as profit-making strategy. And the latter approach is to determine the existence of predictability using past return series or price information. As a pioneer study on the Dhaka Stock Market in this type, it is needed to identify the latter first to test the extent of efficiency. However, the various testing methods widely used are such as normality test [e.g., Laurence (1986), Claessens et al. (1995), Urrutia (1995), Poshakwale (1996, 1997) and Groenewold (1997)], run test [see, for example, Sharma and Kennedy (1977), Roux and Gilbertson (1978), Branes (1986), Laurence (1986), Dickinson and Muragu (1994), Urrutia (1995) and Poshakwale (1996, 1997)], serial correlation or auto-correlation test [e.g., Laurence (1986), Claessens et al. (1995), Poshakwale (1997), Groenewold (1997) and Khababa (1998)], spectral analysis [Granger and Morgenstern (1963) Sharma and Kennedy (1977)], variance-Ratio test [Lo-Mackinlay's (1988) Ojah and Karemera (1999) and Groenewold (1997)] and regression analysis including auto-regression; dynamic time series model such as ARMA and ARIMA model [Fama and French (1988) and Poterba and Summers (1988)]. This study applied most of the techniques [traditional and dynamic] excluding spectral and variance ratio test. The daily data used in this paper is not suitable for the spectral analysis and variance ratio test.

[1] The study considers only the equally weighted indices because value weighted indices are not available.

However, the empirical test in the study uses a multi-approach or triangulation of statistical techniques rather than an individual approach which makes it easier to compare the results from different findings and also increases the reliability of this research. This study includes both non-parametric tests (such as Kolmogrov–Smirnov goodness of fit test and run test) and parametric tests (such as Auto-correlation coefficient test, Auto-regression test and dynamic time series model Auto-regressive Integrated Moving average model or ARIMA). In choosing the analytical techniques we considered the following issues: first, the research needed triangulation between developed and less developed markets (supporting the view of Dickinson and Muragu 1994). Triangulation in research may be theoretical or implemented through the use of different research methods, different settings, different data and improved decision making techniques and so on. Second, the study considers both robust traditional tests such as the run test and Auto-correlation test and dynamic time series techniques such as Auto-regression test and the ARIMA model, which perhaps claim better findings. Third, a recent approach to the study of the predictability of stock market returns in developed markets also includes the variance ratio test (Lo and Mackinlay 1988) and regression analysis (Poterba and Summers (1988) and Jagadeesh (1990). This study also employs the time series regression analysis considering the lag of returns and current returns in Auto-regression analysis which helps to determine whether the returns are predictable from the past returns and also to find the extent of dependency. In addition, this study runs ARIMA, the dynamic time series model to examine whether the stock return series depends not only on its past values of the return series but also on past and current disturbance terms. When the share returns can be predicted on the basis of data on past returns and on forecasted past errors together this gives rise to the ARMA model. It is assumed that if stock return is a function of it's past values of stock returns itself or the current and past values of the disturbance terms means predictability of returns. This study uses the ARIMA model instead of the ARMA one because it includes the integration process. Finally, the robustness of the results is assessed in various ways. First, similar tests are conducted for various sub-samples of the original sample and by trimming outlying observations. Second, this study considers individual actively traded shares return to get results free of thin trading bias. And third, the use of different testing procedure helps to reach a final conclusion and to examine the consistency of the findings (for example, Urrutia 1995 finds different findings from run test and variance ratio tests). In short, this study restricts attention exclusively on the predictability of returns in a less developed market using the combinations of robust and dynamic techniques.

In particular, this study follows the methodology used by Claessens et al. (1995) and Poshakwale (1997) in emerging markets.[2] Moreover, there are some additional time series models used in this study like the Auto-regression analysis and ARIMA model to confirm the results of other analysis as well as to see the predictive ability of the fitted model. In the return predictability, this study excludes the 'week-end effect', which has been documented internationally (Jaffe and Westerfield 1985) and these effects largely persist despite different institutional arrangements (Brown et al. 1983).

The daily market returns are used as an individual time-series variable.[3] The daily share price indices include all the listed stocks. The study calculates market returns from the daily price indices without adjustment of dividend, bonus and right issues. The reason is that many researchers confirm that their conclusions remained unchanged whether they adjusted their data for dividend or not (for example, and Fishe et al. 1993; Lakonishok and Smidt 1988). As mentioned earlier, this study mainly uses the daily market returns as an individual variable in time series analysis. In addition, individual companies' daily share returns are also considered as an additional variable to avoid the thin trading bias. DSE prepares a daily price index from the equally weighted-average price of daily transactions of each stock. Daily market returns (R_{mt}) are calculated from the daily price indices as follows:

$$R_{mt} = \text{Ln}\left(\frac{PI_t}{PI_{t-1}}\right) \tag{1}$$

where,
R_{mt} = market return, in period t; PI_t = price index at day t; PI_{t-1} = the price index at period $t-1$ and Ln = natural log.

[2] Claessens et al. (1995) use two different additional tests such as the variance ratio test and cross-sectional regression analysis and Poshakwale (1997) includes the weekend effect.

[3] 'The EMH gives no indication of the horizon over which the returns should be calculated. The tests therefore be done for alternative holding period of a day, week, month or even years', Cuthbertson 1996: 117.

The reasons to take logarithm returns are justified both theoretically and empirically. Theoretically, logarithmic returns are analytically more tractable when linking together sub-period returns to form returns over longer intervals.[4] Moreover, empirically logarithmic returns are more likely to be normally distributed which is a prior condition of standard statistical techniques (Strong 1992). For individual companies, the daily returns are calculated adjusting ex-dividend as:

$$LNSHRET = \text{Ln}\left[\frac{P_t + D_t}{P_{t-1}}\right] \qquad (2)$$

where, *LNSHRET* is the natural logarithm of returns on individual security, P_t is the daily price per share at time t, P_{t-1} is the daily price per share at time $t - 1$, D_t is the dividend per share of an individual security.

4. Empirical Analysis and Discussion

The empirical results are discussed according to each individual statistical analysis. One of the basic assumptions of the random walk model is that the distribution of the return series should be normal. Under the random walk model, the behaviour of prices under EMH will wander randomly with or without drift (around an increasing trend). A random walk model with drift implies that the expected price changes can be non-zero. A stochastic variable is said to follow random walk with drift parameter δ, when

$$X_{t+1} = \delta + X_t + \varepsilon_{t+1} \qquad (3)$$

where, εt_{t+1} is an identically and independently distributed random variable:

$E\varepsilon t_{t+1} = 0$, a random walk without drift $\delta = 0$.

In order to test the distribution of the return series, the descriptive statistics of the log of the market returns are calculated and presented in Table 1.

From Table 1, it can be seen that the frequency distribution of the return series is not normal. The non-normal frequency distributions of the stock return series deviate from the prior condition of random walk model.

[4] Poshakwale (1997) describes this clearly.

Table 1
Descriptive Statistics of the Daily Market Return
(Log of the Individual Company's Return and Average Market Returns)

Variable	*Mean (Std Error)*	*Median*	*Std.*	*Minimum*	*Maximum*
Stock 1	–4.40 (.04)	.000	1.19	–8.6	–.11
Stock 2	.008 (.0012)	.000	.035	–.23	.21
Stock 3	–.0006 (.0009)	.000	.053	–2.09	.63
Stock 4	–.0001 (.0001)	.000	.073	–1.92	1.89
Stock 5	.0001 (.0006)	.000	.039	–.46	.47
Stock 6	–.0002 (.0001)	.000	.06	–2.81	.59
Stock 7	.002 (.0003)	.000	.018	–.60	.43
Stock 8	–.0001 (.0006)	.000	.038	–.69	.32
Stock 9	–.0001 (.0005)	.0000	.086	–3.15	3.04
Stock 10	.0001 (.0004)	.000	.039	–.54	.65
Stock 11	–.0007 (.0007)	.000	.038	–.55	1.10
Stock 12	.0002 (.0006)	.000	.031	–.42	.47
Stock 13	–.0004 (.0008)	.000	.044	–1.07	1.08
Stock 14	.0003 (.0004)	.000	.0193	–.69	.25
Stock 15	–.0004 (.0006)	.000	.0317	–.34	.67
Stock 16	–.0004 (.0004)	.000	.022	–.69	.33
Stock 17	.0008 (.0006)	.000	.031	–.69	.73
Stock 18	–.0005 (.0018)	.000	.0953	–2.95	2.95
Stock 19	–.0003 (.0004)	.000	.0235	–.47	.53

(*Table 1 continued*)

(*Table 1 continued*)

Variable	*Mean (Std Error)*	*Median*	*Std.*	*Minimum*	*Maximum*
Stock 20	.0010 (.0006)	.000	.0335	–.48	.77
Stock 21	.0001 (.0007)	.000	.038	–.88	.69
Stock 22	.0006 (.005)	.000	.027	–.14	1.31
Stock 23	–.0002 (.0005)	.000	.025	–.25	.25
Stock 24	–.0003 (.0006)	.000	.035	–.49	.51
Stock 25	–.0003 (.0006)	.000	.033	–.92	.45
Stock 26	–.0005 (.0015)	.000	.0888	–2.50	2.54
Stock 27	–.0005 (.0009)	.000	.0546	–2.31	.41
Stock 28	–.0001 (.0006)	.000	.0376	–1.4	.36
Stock 29	–.0001 (.0008)	.000	.044	–.22	.01
Stock 30	.0002 (.0009)	.000	.0465	–1.24	.43
Average Index Return	.0001 (.0003)	.00	1.95	–.35	.33

To confirm the distribution pattern of the stock return series Kolmogrov Smirnov Goodness of Fit test is also used which provides further evidence whether the distribution confirms to a normal distribution or not. It is important to note that this study uses two different non-parametric tests; one is Kolmogrov Smirnov Goodness of Fit test and the other is the run test to prove if the daily return series follows the random walk model.

The Kolmogrov Smirnov Goodness of Fit test (K-S test) is a non-parametric test and is used to determine how well a random sample of data fits a particular distribution (uniform, normal and Poisson). The one sample K-S test compares the cumulative distribution function for a variable with a uniform or normal distribution and test whether the distributions are homogeneous. We use both normal and uniform parameters to test the distribution. Results from Table 2 (K-S test) show a 0.00 probability for *Z*, clearly indicating that the frequency distribution of the daily return series on the Dhaka Stock Exchange does not fit by normal distribution. In short, the normality test of both descriptive statistics and the K-S test document that the return series exhibit non-normal distribution. The non-normal distributions of the stock return series on the DSE resembles those found in other markets such as Australia and New Zealand (Groenewold 1997), India (Poshakwale 1996, 1997) and Kuala Lumpur and Singapore (Laurence 1986) stock markets. This might be due to high volatility of the stock price series on the Dhaka stock market like in the other emerging market (see for example, Harvey 1994).

Table 2
Kolmogrov Smirnov Goodness of Fit Test: (Daily Market Return)

Distribution	*Absolute*	*Positive*	*Negative*	*K-S Z*	*Z- Tailed P*
Normal	.251	.251	–.248	14.709	0.00

The run test is another non-parametric test approach to test and detect statistical dependencies (randomness), which may not be detected by the parametric Auto-correlation test. The test is well-known and widely used to prove the random walk model because it ignores the properties of distribution. Null hypothesis of the test is that the observed series is a random series. The numbers of runs are computed as a sequence of price changes of the same sign (such as: ++, – –, 0 0). When the expected number of runs is significantly different from the observed number of runs it implies that the null hypothesis of randomness of the daily return series is rejected. The run test converts the total number of runs into a *Z* statistic. For large samples the *Z* statistics gives the probability of difference between the actual and expected number of runs. The *Z* value is greater than or equal to ±1.96; reject the null hypothesis at 5 per cent level of significance (Sharma and Kennedy 1977).

The question of whether a sequence of observed numbers (i.e., the individual company's daily share price series or daily share price index series) is a random sequence can be studied by the number of runs observed in the series. The number of runs is computed as a sequence of the price change of the same sign. The actual number of runs is compared with the expected number of runs, irrespective of the sign.

The null and alternate hypothesis for the run test is as follows:

H0: The observed series is a random series.
H1: The observed series is not a random series.

The test statistics for the number of runs is computed as follows:

Expected number of Runs (R), $E(R) = n + 2/2$, Var (R) $= n(n - 2)/4(n - 1)$,

The actual number of runs (R) is computed as $\sum_{i=1}^{n} R_i$

where $R_i = 1$, if $\mu_i < \mu_{i+1}$, $i = 1, 2, ..., n$,
$= 0$, otherwise.

The test statistics $Z = \dfrac{R - E(R)}{\sqrt{\text{var}(R)}}$

As can be seen from the Table 3 the Z statistics of daily market return is greater than ±1.96 and negative, which means that the observed number of runs is fewer than the expected number of runs with observed significance levels. The result implies a lagged response to information.[5] In addition to this, the observed numbers of runs also indicate a rejection or acceptance of the random walk model.

The number of runs is greater than 20 in all the cases (Table 3) stating that the series return are not following the independent assumption of the random walk model. Therefore, we can reject the null hypothesis that the return series on the DSE follows the random walk model. Moreover, the results of the run test to individual companies' daily share return shows that among the 30 individual companies, in 29 companies Z value is negative and greater than ±1.96, which is consistent with the previous findings that the return series are not following the random walk model. The significant two-tailed with negative Z values greater than ±1.96 also suggest non-randomness because of too few observed numbers of runs than expected. The results are similar to the findings of Poshakwale (1997), who also docu-

[5] As the table value does not represent the expected number of runs, we also calculate the expected number of runs following the formula used by Urrutia (1995). Expected number of runs = $2(n + 1)/3$; where, n = number of observations and the results shows that there is a significant difference between the observed number of runs and expected number of runs.

Table 3
The Results of Run Test (Daily Market Return Series and Individual Return Series)

Particulars of the Variables		*Total Number of Runs(M)*	*Z*	*Asymp Sig (2-tailed)*
Daily market return		1198	–16.75*	.000
Individual company's daily return Serial. No.	Code			
1.	201	1142	–11.04*	0.00
2.	202	956	–15.63*	0.00
3.	203	808	–18.53*	0.00
4.	204	781	–21.07*	0.00
5.	206	1409	–6.79*	0.00
6.	211	878	–19.26*	0.00
7.	251	13	.107	.9147
8.	252	698	–22.54*	0.00
9.	257	464	–22.40*	0.00
10.	259	794	–16.33*	0.00
11.	265	1353	–5.73*	0.00
12.	301	1039	–8.34*	0.00
13.	359	413	–12.91*	0.00
14.	402	1042	–9.46*	0.00
15.	405	29	–9.83*	0.00
16.	406	455	–18.97*	0.00
17.	407	23	–4.58*	0.00
18.	408	305	–24.02*	0.00
19.	453	831	–10.72*	0.00
20.	454	486	–.24.02*	0.00
21.	455	571	–24.16*	0.00
22.	456	439	–23.52*	0.00
23.	457	310	–28.27*	0.00
24.	458	786	–13.84*	0.00
25.	460	580	–24.24*	0.00
26.	551	20	–27.91*	0.00
27.	601	808	–11.11*	0.00
28.	603	988	–9.37*	0.00
29.	605	1099	–11.61	0.00
30.	608	944	–12.70*	0.00
31.	609	327	–29.63*	0.00

Note: * Significant at 1% level.

ments the actual number of runs significantly lower than the expected number of runs for daily returns in India, Philippines, Malaysia and Thailand. Overall, the results of the run test analysis on the Dhaka Stock Exchange indicates that the distribution of the daily share return series on the exchange are not random as the probabilities associated with the expected number of runs are all greater than the observed number of runs. However, the non-random nature of the price series might be due to institutional factors on the DSE contributing to market inefficiency including illiquidity, market fragmentation, trading and reporting delays and the absence of official market makers.

In addition to non-parametric run test, this study investigates the parametric tests to examine if the findings of non-parametric tests confirmed by the findings of parametric tests. In addition, the extent of dependency is also measured with the parameters estimated. Auto-correlation test is conducted in testing either dependence or independence of random variables in a series. The serial correlation coefficient measures the relationship between the values of a random variable at time *t* and its value in the previous period. Auto-correlation tests show whether the correlation coefficients are significantly different from zero.

The basic model for Auto-correlation analysis and for Ljung-Box statistics is:

$$U_t = LnR_{mt} - LnR_{mt-1} \tag{4}$$

The auto-correlation coefficient has been measured by

$$rn = [\text{Covariance } (U_t, U_{t-1}]/[\text{variance } (U_t)]$$

where *rn* is the *n*-th order of auto-correlation coefficient or auto-correlation coefficient having *n*-period lag, U_t is the change of log price of period t to $t - 1$.

In this study, the sample auto-correlation coefficient for daily changes in price has been computed for lag $n = 1, 2, 3, \ldots, 22$. This study used auto-correlation analysis for a large sample (Numbers of observations) Ljung-Box Statistics that follows the Chi-square distribution with m degrees of freedom:

$$LB = n(n+2)\sum_{k=1}^{m}\left(\hat{P}_k^2 / n-k\right) \sim \chi^2$$

where, $\hat{P}\ k$ = Auto-correlation coefficients at lag k;
n = sample size.

In this study, the auto-correlation coefficients have been computed for the log of the market return series showing significant auto-correlation at different lags for the full sample period and without outlier. The results of auto-correlation are presented in Table 4. It is evident that there are significant (positive sign) auto-correlation coefficient at the 5th, 8th, 14th and 19th lag and significant (negative sign) auto-correlation coefficient at the 2nd and 17th lag for the full sample period. The presence of non-zero auto-correlation coefficients in the log of the market returns series clearly suggests that there is a serial dependence between the values. To confirm the results, the auto-correlation coefficient of the return series without outlier and sub-sample periods (1997–2000) considering structural changes like the inauguration of automation on the DSE are also estimated. However, the results from Table 4 confirm that there is a significant auto-correlation of daily market returns for the whole sample period, sub-sample period and

Table 4
Results of Auto-correlation Test (Log of the Daily Market Return)

Lag	*Auto-Correlation (1988–2000)*	*Ljung-Box Statistics (22 df)*	*Auto-Correlation (1997–2000)*	*Ljung-Box Statistics (22 df)*	*Auto-Correlation (Without Outlier)*	*Ljung-Box Statistics (22 df)*
1.	.048	8.00	.121*	15.60**	.111*	42.34**
2.	–.122*	59.01**	–.124*	31.76**	–.035	46.65**
3.	.032	62.55**	.057	35.20**	.033	50.44**
4.	.010	62.88**	.091*	43.99**	.041	56.18**
5.	.077*	83.16**	.048	46.47**	.032	59.70**
6.	.002	83.17**	–.049	49.07**	.007	59.87**
7.	.002	83.18**	–.046	51.33**	–.037	64.47**
8.	.099*	117.08**	.024	51.95**	.028	67.17**
9.	.029	119.95**	–.001	51.95**	.035	71.35**
10.	–.041	125.83**	.051	54.70**	–.007	71.52**
11.	.040	131.22**	.018	55.04**	.005	71.61**
12.	–.065	145.91**	–.099*	65.46**	–.0028	74.21**
13.	.010	146.26**	–.060	69.33**	–.032	77.72**
14.	.102*	182.02**	.065	73.83**	.061	90.73**
15.	.04	184.82**	.007	73.89**	.035	94.95**
16.	.013	185.36**	–.002	73.89**	–.003	94.98**
17.	–.100*	219.87**	–.040	75.61**	–.012*	95.52**
18.	–.004	219.87**	.014	75.82**	–.022	97.14**
19.	.103*	256.26**	.007	75.86**	.013*	97.71**
20.	.033	260.03**	.000	75.86**	.004*	97.75**
21.	.004	260.08**	.042	77.72**	–.010*	98.07**
22.	.013	260.83**	–.042	79.64**	–.019	99.35**

Note: * Significant auto-correlation at two standard error limits; ** LB statistics significant at 1% level of significance.

without outlier. The non-zero auto-correlation of the series associated with Ljung-Box Q statistics that are jointly significant at the 1 per cent level at 22 degrees of freedom (lags) suggests that the return series on the DSE are not following the random walk model. Given the positive auto-correlation momentum strategy that appears to earn superior returns to the market average, it is possible that the large investor who wants to earn higher average returns uses the market timing strategy (buying when the share prices are low and selling when the share prices are high) and other uninformed investors follow the momentum trading.

The results of the auto-correlation tests found in this study are consistent with the findings of Harvey (1994 1995), Claessens et al. (1995) and Poshakwale (1997) in emerging market research. Similarly, Claessens et al. (1995) find that in most industrial economies, first-order auto-correlation are not generally higher than 0.2, whereas eight economies in emerging markets (Chile, Colombia, Mexico, Pakistan, Philippines, Portugal, Turkey and Venezuela) have significant first order auto-correlation greater than .20. The highest first order auto-correlation was .489 in Colombia. Poshakwale (1997) also found significant auto-correlation at various lags of the return series in India, Philippines, Malaysia and Thailand suggesting interdependence in the return series. In short, the results found in the study on the Dhaka Stock Exchange are not inconsistent with the findings in other emerging markets.

Further, this study used the exact maximum likelihood auto-regression technique to examine whether a non-zero significant relationship exists between current return series with the first and second lag values of itself. The coefficient significantly different from zero indicates the predictability of share return from the past return. In the context of the weak-form of efficient market hypothesis (WFEMH), the regression model used according to law:

$$LnP_t = a_1 + a_2 LnP_{t-1} + U_t \tag{5}$$

where,

U_t = random disturbance term

P_t is the price of the stock at time t

a_1 is the part of the stock price that does not depend on the previous price of stock (constant term)

a_2 is the degree to which is the stock price at time t is dependent on the stock price at time $t - 1$.

In this regression model, to test the randomness of stock price changes, it requires to test H0: $a_2 = 1$, that is, the stock price changes are non-random and statistically dependent at a 95 per cent confidence level.

The results presented in Table 5 also exhibit a significant auto-regression coefficient AR_1 (.256) significantly different from zero during the whole sample period. The auto-regression coefficient at the first and second lags being significant at the 1 per cent level of significance proves that the series are not independent and the returns are predictable. The result does not differ significantly when we exclude the outlier. It is important to note that the results are consistent with the auto-correlation tests. However, the null hypothesis that the return series are independent is rejected in all cases.

Table 5
(Results of Auto-Regression Test of the Daily Return Series)

Variables in the Model (Overall 10 YRS)	*Coefficients*	*SEB*	*T-Ratio*	*Approx. Prob.*
AR_1	.256*	.0599	4.27	.000
LnR_{mt-1}	–.196*	.0168	–11.64	.000
LnR_{mt-2}	–.177*	.0168	–10.53	.000
CONSTANT	.0204	.0004	.215	.830
Variables in the model (without outlier)				
AR_1	.1517*	.0268	5.644	.000
LnR_{mt-1}	–.008*	.013	–.627	.051
LnR_{mt-2}	–.068*	.013	–5.313	.000
CONSTANT	.00002	.083	.3281	.74289

Note: * denotes significant at 1% level.

In addition to the above statistical techniques, this study ran ARIMA, the dynamic time series model to examine whether the stock return series depends not only on its past values of the return series but also on past and current disturbance terms. ARIMA stands for Auto-regressive Integrated Moving Average, including the three components of the general ARMA model.

ARIMA models combine as three types of processes: auto-regression (AR); differentiating to strip off the integration (I) of the series; and moving average (MA). The general model, neglecting seasonality, is written as ARIMA (p, d, q) where p is the order of auto-regression, d is the degree of differencing and q is the order of moving average involved.

In an auto-regressive process, each value in a series is a linear function of the preceding value or values. That is, in a first order auto-regressive process, only the single preceding value is used; in a second process, the two preceding values are used and so on. For example:

AR(1) is first order auto-regressive process, where,

Value t = disturbance $t + \theta$ value $t - 1$

For example, in this study,

$$LnP_t = \varepsilon_t + \theta LnP_{t-1} \tag{6}$$

We can study an integrated series by looking at the changes or differences from one observation to the next. This type of I (1) process is often called a random walk because each value is a random step away from the previous value. Degree of differencing depends on the non-normality of the data series and also on converting the non-stationary data to a stationary series.

The process uses data on past forecasted errors. Each value in a series is determined by the average of the current or more previous disturbance terms.

i.e., Value t = disturbance $t - \theta *$ disturbance $t - 1$

In this study, if it is first order moving average MA(1) is used then the equation will be as follows:

$$LnP_t = \varepsilon_t - \theta\varepsilon_{t-1} \tag{7}$$

where, ε is the disturbance term.

Ultimately, the ARIMA model is a combination of both equations 6 and 7 including the differencing of the data series first.

$$\text{i.e., } LnP_t = f(LnP_{t-1}, \ldots, n, \varepsilon_{t-1}, \ldots, n) \tag{8}$$

However, this study uses the ARIMA model instead of the ARMA model because it includes the integration process. As we know under the random walk model, it needs to fit the model in ARIMA (0, 1, 0) where the future value of share returns cannot be determined on the basis of past information. Specifically, future share returns will not depend on past (lag) values of share returns or on the past error terms. The significant coefficients of auto-regression (AR) or moving average (MA) different from zero suggest dependency of the series which violates the assumption of the random walk model and weak-form efficiency.

Results from Table 6 suggest that the return series on DSE are not following the random walk model. As mentioned earlier, ARIMA (0, 1, 0) supports the random walk model. We first calculate ARIMA (0, 1, 0) of the daily return series for the whole sample period, where the coefficient is .000001 (.00044) with a *t*-ratio (.0025) and probability of .999. And in diagnostic checking, the significant residual auto-correlation at 2, 4, 5, 8, 10, 12 and 14 lags suggests that the model is not well fitted. During the whole sample period, ARIMA (2, 0, 1) is found as the best fitted model with AR_1 coefficient (–.519); AR_2 (–.0864); and MA_1 (–.585) significant at the 1 per cent level of significance. The diagnostic checking shows that there is no significant residual auto-correlation in the return series. In addition to ARIMA (0, 1, 0) and ARIMA (2, 0, 1) we also run ARIMA (1, 0, 0) for the entire sample period to examine whether the auto-regression coefficient (AR_1) is equal to one or unity. It should be noted that when the auto-regression coefficient is equal to unity, it implies that the changes of returns from one period to another period are only due to current disturbance terms. That is the return series do not depend on past information of the return series or past forecasted errors. But the results presented in Table 6 report that the coefficient is only .048, which means that the changes in the return series are not due to the current disturbance terms, which does not support the random walk model and is consistent with previous tests. In short, all

Table 6
Results of ARIMA Model [ARIMA (0, 1, 0), ARIMA (2, 0, 1), and ARIMA (1, 0, 0)] for the Daily Market Return Series

ARIMA (0, 1, 0)	*Coefficient*	*SE*	*T-ratio*	*Prob.*
CONSTANT	.000001	.00044	.0025	.999
ARIMA(2, 0, 1)				
AR_1	–.519*	.0815	–6.37	0.000
AR_2	–.0864*	.0207	–4.18	0.000
MA_1	–.585*	.0809	–7.23	0.000
CONSTANT	.00006	.0003	.214	.8309
ARIMA(1, 0, 0)				
AR_1	.0483**	.0171	2.83	.004
CONSTANT	.0006	.0003	.1986	.843

Note: * denotes significant at 1% level and ** denotes significant at 10% level.

the evidence suggests that there is a significant dependency of past returns information on the DSE, which is against the weak-form efficiency of the market and proves that the past return series can be used to predict future returns. This predictability nature of the DSE price series might be due to a lower degree of efficiency like in the markets in other less developed countries persisting with common characteristics of loose disclosure requirements, thinness and discontinuity in trading and the less developed nature of the markets. As we know the independence hypothesis needs to be justified by the existence of risk free assets, negligible non-diversifiable risk and a perfect market assumption. Clearly, conditions in the Dhaka stock market are far away from this idealised vision of the world than they are in major developing countries markets.

The robustness of the results of the study is assessed using different statistical tests and finding the consistency of the results, which eventually increases the reliability of the results. As we know there are two types of econometric problems faced in this type of research: one is non-normal distribution and the other is heteroskedasticity. This study considers the logarithmic returns instead of discrete returns. In addition, the study uses both parametric and non-parametric tests, the latter ignores the distribution to be normal or not. To prevent heteroskedasticity problems in OLS regression, the study considers the exact maximum likelihood auto-regression techniques, which are free from this bias. In choosing the best fitted model in the ARIMA model, we considered two main diagnostic checkings: first, ACF (Auto-correlogram function) of the residual errors accept the null hypothesis that the residuals are white noise (Box-Ljung probability is not significant). Second, for a given series with different models the lower AIC (Akaike Information Criterion) and SBC (Schwartz Baysian Criterion) were considered in selecting the best-fitted model.[6]

However, the results presented in the study do not investigate the aspects of the profit-making strategy in detail using any technical trading rules or adjusting transaction costs (such as bid-ask spread, brokerage fee and time lag of settlement procedures) and as a result we can reach no conclusion in this regard. Similarly, using equally weighted indices may bias the results. However, we have tried to overcome the problems of non-trading bias by

[6] AIC = T. ln (residual sum of squares) $+2n$; and SBC = T. ln (residual sum of squares) $+n$ ln (T); where, T = number of useable observations and N = number of parameters estimates.

considering the actively traded individual companies' daily share return series in the run test. And the result of individual share returns also show that the return series are not independent.

5. Concluding Remarks

The findings of the study support some studies in emerging markets (e.g., Roux and Gilbertson 1978; Ghandi et al. 1980; Errunza and Losq 1985; Laurence 1986; Butler and Malaikah 1992; Cheung et al. 1993; Harvey 1994; Claessens et al. 1995 and Poshakwale 1996, 1997) whereas they do not support some others on emerging markets (e.g., Sharma and Kennedy 1977; Branes 1986; Chan et al. 1992; Dickinson and Muragu 1994; Urrutia 1995 and Ojah and Karemera 1999). These controversial findings from the emerging markets research make the study interesting to compare among the emerging markets. The Dhaka stock market seems to be like some other emerging markets such as the Indian market, the Johannesburg Stock Exchange, the Kuwaiti stock market, some of the Middle Eastern markets and the Korean and Taiwan markets. However, this may be due to similar types of characteristics prevailing in these markets such as thin trading, volatility, small number of securities listed, investors' attitude towards investment strategy, institutional framework and price forming information that may not be disseminated rapidly because of lack of intensive market regulations and markets are themselves at the speculation stage.

This study supports the new thinking of Shleifer (2000) that the assumptions of efficient market hypothesis about investors' rationality and perfect arbitrage contradict with both psychological and institutional evidence in the real world. So, this study supports the work on the lack of previous theory and suggests Shleifer's (2000) 'behavioural finance' as an alternative view for studying financial markets. There are also some practical implications of the results for market participants and regulators. In fact the market anomalies, found in DSE, are due to a newly established emerging market where the regulatory system and the trading mechanisms under which it is operated are not as developed as compared to mature and developed markets. However, the potential importance of this study for capital market participants may be categorised as follows: First, the dependence found in the return series may be due to the lack of information disclosure requirements and private information in the market. The lack of effectiveness of the regulatory bodies and the lower standards of law enforcement are major causes of distortions in the less developed financial markets. Hence, it is an important issue to concentrate on legal aspects of emerging markets regarding information disclosure requirements, protection of outside investors' interests and preventing the market from current irregularities. Second, it may be helpful to have improved regulatory disclosure rules for investors and financial analysts who are participating directly in the stock market. They will be better equipped to make more accurate predictions about future stock returns. At present there is no such model that can be used for predicting stock returns in Bangladesh. Third, long-run dependence may be harmful as it decreases investors' confidence and reduces market depth and breadth. This study emphasises on the need to improve market conditions because the stock market in Bangladesh may fail to deliver desired results without structural and regulatory changes to the market. An improved trading mechanism with a central depository system and an investment banking industry are needed to increase the capacity of the exchange. At the same time effective regulations that curb market manipulation and ensure full disclosure to investors are essential. When the operational and informational efficiency in less developed markets is maximised the market will be more efficient, which will eventually increase the investors' confidence and contribute higher levels of economic activities. Finally, this study of an individual market explores the special nature of the market and when studies are conducted in-depth in different markets, it may be easier to come to a general conclusion. More empirical research using established large computerised data based on market prices information and individual investors' trades should be take into consideration to make an attempt to understand market anomalies.

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