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A TEST OF THE WEAK-FORM OF THE EFFICIENT MARKET HYPOTHESIS: EVIDENCE USING DAILY DATA FROM THE COLOMBO STOCK EXCHANGE

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Introduction

A large amount of empirical evidence drawn from the world's major stock markets has tended to support the Efficient Market Hypothesis (EMH). While no universal agreement on a definition of efficiency exists, the general definition of Fama (1970) that a market is efficient if share prices "fully reflect all information available" (p. 383) has become widely accepted; it should not be possible to consistently outperform the market, after adjusting for differences in risk, by trading on information in an efficient market; in Fama's terminology the market is a "fair game".

Fama classified the efficiency of the market into three categories depending on the information which is fully reflected in share prices. First, he argued that a market was weak-form efficient if the "information available" includes historic share price data; it should not be possible for an investor to make abnormal profits on a regular basis simply by looking at past share prices and extrapolating into the future on the basis of apparent trends or patterns in the data. This aspect of the EMH is commonly described using the phrase "markets have no memory" (Brealey and Myers, 1991, p.300). Second, he proposed that a market is semi-strong-form efficient if the information fully reflected in share prices includes all publicly available data; the market reacts to news quickly and correctly impounding all the publicly available information about a company instantaneously into its share prices leaving no opportunity to earn abnormal returns using trading strategies based on such publicly available information. Finally, Fama suggested that a market was strong-form efficient if share prices fully reflect all information both public and private so that even an investor who had monopolistic access to privileged information could not consistently earn above average returns trading on such information.

While all three forms of efficiency have been investigated it is the first of these which we hope to examine. The basic objective of this paper is to conduct a statistical analysis of share prices to examine whether the Colombo Stock Exchange (CSE) is weak-form efficient. The test of weak-form efficiency observes whether mechanical rules based on historical share price information can be used to predict future share prices in an attempt to earn profit in excess of the average market return. This approach in turn tests the randomness of successive changes in share prices over a particular time period; the testing of the validity of the Random Walk Hypothesis (RWH)[1] as an explanatory model of price behaviour has become a common practice in the finance literature.

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[1] In statistical terms the Random Walk Hypothesis says that successive changes in share prices are independent, identically distributed random variables so that the future path of the price level of a security is no more predictable than the path of a series of cumulated random numbers.

The bulk of the research into the behaviour of stock market prices has been confined to the capital markets in developed countries such as the US and the UK where computerised databases (i.e. Compustat and Datastream) are available. The number of studies are numerous to cite but the findings of pioneering early studies such as Kendall (1953), Roberts (1959), Alexander (1961), Cootner (1962), Fama (1965), King (1966), Moore (1967), Griffiths (1970), Granger and Morgenstern (1970), Brealey (1970), Dryden (1970a, 1970b), Cunningham (1973), and Girmes and Benjamin (1975) are well documented.[2] A second group of studies in the early 1970s focused on smaller and less developed stock markets covering a variety of different countries. For example, Praetz (1969, 1973) analysed Australian share prices; Conrad and Juttner (1973) studied German share price changes; Niarchos (1971) investigated Greek Stock Market data; Solnik (1973) analysed share prices from Belgian, British, Dutch, French, Italian, German, Swiss and Swedish stock markets; Affeleck-Graves and Money (1975) investigated the efficiency of the Johannesburg Stock Exchange; Jennergren (1975) tested for patterns in Norwegian Stocks; and Jennergren and Korsvold (1975) examined the behaviour of Swedish share prices. However, recent finance literature reveals a growing number of studies of new stock markets; Ang and Pohlman (1978) studied five Far Eastern stock markets including Hong Kong, Japan, Malaysia and Singapore; Gandhi, Saunders and Woodward (1980) investigated the efficiency of the Kuwaiti stock market; Cooper (1982) examined the efficiency of 50 stock exchanges including Brazil, Chile, Colombia, Egypt, India, Israel, Mexico, Peru and Philippines; Parkinson (1987) and Dickinson and Muragu (1994) analysed the share returns of Nirobi Stock Exchange while Lian and Leng (1993) studied the Malaysian Stock Market. All these recent articles provide an extensive literature regarding the weak-form efficiency of some of the world's newest stock markets. Many of these studies, even though their evidence is less pronounced than the findings of the empirical investigations which were based on the US and the UK markets, support the validity of the weak-form efficiency of the various capital markets and therefore of the RWH as an explanatory model of the behaviour of share prices.[3]

Data

One of the major problems encountered by researchers in investigating the stock markets in developing countries is the non-availability of data from computerised databases. The problems of carrying out research in such a situation have been documented by Russel (1972), Solnik (1973) and Dickinson and Muragu (1994). Until recently, data for the emerging stock markets have not been available from computer databases such as Datastream and this problem is equally applicable to CSE; the share price data for the companies quoted on the CSE became available from Datastream only from 1993. This limitation

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[2] Cootner (1967) and Richards (1979) provide an extensive collection of readings along with relevant bibliographies.

[3] Table 1 provides a summary of major empirical studies which are associated with the weak-form of the EMH.

Table 1: A Summary of the Major Empirical Studies Associated with the Weak Form of the EMH.

Author	Country	Data Analysed	Time Interval	Average Correlation Coefficient
Kendall (1953)	UK	19 Indices	1 week	0.131
			2 weeks	0.134
			4 weeks	0.006
			8 weeks	-0.054
			16 weeks	0.156
Moore (1967)	US	30 Companies	1 week	-0.056
Cootner (1962)	US	45 Companies	1 week	-0.047
			14 weeks	0.131
Fama (1965)	US	30 Companies	1 day	0.026
			4 days	-0.039
			9 days	-0.053
			16 days	-0.057
King (1966)	US	63 Companies	1 month	0.018
Niarchos (1971)	Greece	15 Companies	1 month	0.036
Praetz (1969)	Australia	16 Indices,	1 week	0.000
		20 Companies	1 week	-0.118
Griffiths (1970)	UK	15 Companies	9 days	-0.026
			1 month	0.011
Jennergren (1975)	Norway	15 Companies	1 day	0.068
			2 days	-0.070
			5 days	-0.004
Jennergren and Korsvold (1975)	Sweden	30 Companies	1 day	0.102
			3 days	-0.021
			5 days	-0.016

prevented us carrying out a comprehensive investigation using data for a long period spanning a number of years. This study therefore uses daily share price data for the most frequently traded 20 shares over a 16-month period - April 1993 to July 1994 - which generated 347 observations for each security. Although a sample which only includes the most frequently traded shares may generate a bias in favour of the EMH in research findings, since such shares may presumably be the most heavily researched by Sri Lankan investors, the authors had to rely on this sample in order to overcome problems associated with thin trading in the statistical test procedures.[4]

Methodology

If share prices follow a random walk, the successive changes in share prices should be independent, identically distributed random variables so that future price changes cannot be predicted from historical price changes. Following the RWH the behaviour of share prices can be expressed by the following model.

$$P_{it} = P_{it-1} + U_{it} \tag{1}$$

where, P_{it} is the price of the share i in time t, P_{it-1} is the price of share i in time t-1 and U_{it} is the random error term which is distributed independently of U_{it-1}, U_{it-2} etc. having constant variance. The variable of interest of the study is U_{it}, the change in share price, and the actual tests were performed (following Fama, 1965; Praetz, 1969; Solnik, 1973; Cooper, 1982; and Dickinson and Muragu, 1994) on the first difference of the natural logarithm of daily share prices which took the following form.

$$U_{it} = Ln(P_{it}) - Ln(P_{it-1}) \tag{2}$$

or

$$U_{it} = Ln\left(\frac{P_{it}}{P_{it-1}}\right) \tag{3}$$

where, U_{it}, P_{it} and P_{it-1} are as defined earlier and the Ln is the natural logarithm.[5]

Tests of weak-form efficiency tend to fall into two broad categories; (1) the application of statistical tests to time series of changes in share prices in order to establish the statistical independence of such series and (2) the employment of mechanical trading strategies, based upon historical price data, advocated by

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[4] One recommended approach to overcome data non-availability and thin trading problems is the use of market indices which, for many exchanges, are published and are therefore readily available. But the use of market indices in share price studies is inappropriate for two reasons. First, the market index reveals the average movements in the overall market but not the movements of the price changes in individual securities. Second, the use of the market index may introduce a serial correlation to the analysis depending upon the way the index is weighted.

[5] Fama (1995, pp. 45-46) provides three reasons for using changes in log prices rather than simple price changes. First, the change in log price is the yield, with continuous compounding, from holding the security for that day. Second, the variability of simple price changes for a given share is an increasing function of the price level of the security and taking logarithms seemed to neutralise most of this price effect. Third, for changes less than plus or minus 15 per cent the change in log price is very close to the percentage price change, and for many purposes it is convenient to look at the data in terms of percentage price changes.

professional analysts which purport to outperform a naive buy and hold strategy. The tests employed in this study fall into the first category; we employ serial correlation analysis and runs analysis in an attempt to determine the statistical dependence of time series of successive share returns. The application of these techniques for Sri Lankan data may provide evidence for the robustness of traditional models in current research as they did in 1960s. Furthermore, it may provide new empirical evidence based on a developing stock market for the weak-form efficiency of the EMH.

The serial correlation coefficient provides a measure of the relationship between the value of a random variable in time t and its value k periods earlier. Therefore, for the change in log price for a given share from the end of day t-1 to day t (defined earlier as U_{it}) the serial correlation coefficient for lag k is given by:

$$r_k = \frac{\text{Covariance}(U_{it}, U_{it-k})}{\text{Variance}(U_{it})} \quad (4)$$

If the distribution of U_i has finite variance, then for large samples the standard error of the serial correlation, r_k, can be computed as:

$$\sigma(r_k) = \frac{1}{\sqrt{(N-k)}} \quad (5)$$

where, N is the sample size (see Kendall, 1948, p. 412). The hypothesis tested in this study was that the correlation coefficients of successive daily price changes of 20 shares on the CSE at lag k (k= 1, 2, ..., 15) were zero. For this purpose serial correlation coefficients, r_k, were computed for each company across 15 lags and the hypothesis was tested using a two-tailed test; a coefficient was considered to be statistically significant if it exceeds plus or minus 1.96 of its standard error, $\sigma(r_k)$.

A run is defined as a sequence of consecutive share price changes of the same sign; a plus run of length i is a sequence of i consecutive positive price changes preceded and followed by either negative or zero changes. For share price changes there are three different types of possible price changes - positive, negative and zero - and therefore three possible types of run. If the assumption holds that the sample proportions of positive, negative and zero price changes are good estimators of the population proportions, and the independence hypothesis applies to the sequence of price changes, then the total expected number of runs of all signs for a share (m) can be computed as:

$$m = \frac{N(N+1) - \sum_{i=1}^{3} n_i^2}{N} \quad (6)$$

where, N is the total number of price changes and the n_i (i = 1, 2, 3) are the number of price changes of each sign (i.e. positive, negative, zero). The standard error of m is given by:

$$\sigma_m = \sqrt{\frac{\sum_{i=1}^{3} n_i^2 \left[\sum_{i=1}^{3} n_i^2 + N(N+1) \right] - 2N \sum_{i=1}^{3} n_i^3 - N^3}{N^2(N-1)}} \tag{7}$$

and for large N the sampling distribution of m is approximately normal. Since for large samples the distribution of the total number of runs is approximately normal with mean, m, and standard error, σ, then the difference between the actual number of runs, R, and the expected number of runs can be expressed by means of the usual standardised variable, Z, as follows:

$$Z = \frac{\left(R + \frac{1}{2}\right) - m}{\sigma_m} \tag{8}$$

where, R is the actual number of runs and $\frac{1}{2}$ in the numerator is a discontinuity adjustment. The computed value of Z is significant at 5 per cent level if it lies beyond its critical value.

Results

Some return characteristics of the 20 shares used in this study are reported in Table 2; the mean, standard deviation, minimum and maximum return are included. A wide range of average values are reported. For example, a number of shares performed well over that period; the highest average daily return of 0.0037 was reported by Blue Diamonds Jewel.While the next best performance was achieved by Lanka Tiles and Nestle Lanka. On the other hand, some shares performed poorly; four companies - Asian Cotton Mills, Carsons Marketing, Korea Ceylon Footwear and Seylan Trust Bank - earned negative returns over the time period being considered.

The excellent share performance of Blue Diamonds Jewel. Company was accompanied by levels of risk (as measured by standard deviation) which were small in comparison to standard deviations of other shares in the sample. For example shares in the Ceylon Oxygen Company earned a share return of 0.0004 (less than 1/9th the average return of the Blue Diamonds Jewel. Company) with over six times the level of risk; shares in this company were associated with particularly volatile returns since the standard deviation was 0.2548 and the minimum and maximum returns were large. Overall, the picture emerging from an analysis of the descriptive statistics for the 20 shares in the sample is a mixture of performance with some companies doing better than the others.

Table 2: Return characters of the sample companies.

Security	Average Return	Standard Deviation	Minimum Return	Maximum Return
Aitken Spence Hotels	0.0009	0.0447	-0.2856	0.2831
Asian Cotton Mills	-0.0012	0.1078	-1.3280	1.3093
Asiri Hospitals	0.0017	0.0556	-0.2231	0.3448
Blue Diamonds Jewel.	0.0037	0.0376	-0.1699	0.2669
Carsons Marketing	-0.0005	0.0680	-0.4055	0.3365
Central Industries	0.0014	0.0272	-0.1446	0.1297
Ceylon Grain Elevators	0.0016	0.0332	-0.2763	0.2763
Ceylinco Insurance	0.0017	0.0442	-0.1586	0.2564
Ceylon Oxygen	0.0004	0.2548	-2.3979	2.4111
Compack Morrison	0.0004	0.0554	-0.2412	0.2624
CT Land Development	0.0005	0.0511	-0.2364	0.3483
Ceylon Tobacco Company	0.0008	0.0397	-0.1431	0.2077
Korea Ceylon Footwear	-0.0003	0.0480	-0.5245	0.1912
Lanka Aluminium Industries	0.0016	0.1147	-1.2644	1.2809
Lanka Milk Foods	0.0009	0.0390	-0.2088	0.1793
Lanka Tiles	0.0027	0.0376	-0.1473	0.2187
Merchant Bank of Sri Lanka	0.0012	0.0493	-0.4520	0.2136
Nestle Lanka	0.0026	0.0430	-0.2938	0.2231
Seylan Trust Bank	-0.0001	0.0410	-0.2934	0.1431
United Motors	0.0007	0.0401	-0.1508	0.2412

Serial Correlation

The results of the serial correlation analysis are reported in Table 3.[6] A brief perusal of Table 3 indicates that, on average, correlation coefficients are small in magnitude with largest values being reported by Ceylon Oxygen (-0.503), Asian Cotton Mills (-0.426) and Lanka Aluminium Industries (-0.326) where all the coefficients were negative and statistically significant. The highest serial correlation was exhibited at lag 1 where 7 coefficients (35 per cent of the sample) were statistically significantly different from zero indicating some degree of linear dependence in successive share price changes. The next highest level of serial correlation was present at lag 2 and lag 3 where 5 and 4 coefficients (25 and 20 per cent) respectively were statistically significant; statistically significant coefficients did not exceed 10 per cent at any of the other lag intervals. However,

6 Serial correlation results for only lag inervals of 1-5, 10 and 15 are reported in the table. A complete set of results for all the lag intervals are available from the authors upon request.

most of the significant coefficients were too small in absolute terms to be of any use for forecasting purposes of future share price changes; they range in value from -0.503 to 0.209 which are substantially less than one.

The vast majority of the coefficients were not statistically significantly different from zero at the 5 per cent level; the hypothesis of independence of successive changes in share prices could not be rejected for 277 out of 300 coefficients - 92.33 per cent. In addition there was very little evidence of pattern in the sign of the coefficients with 46.67 per cent being positive and 53.33 per cent negative. This suggests that there was no tendency for price changes in one direction to be followed, with a lag, by changes in the same or in an opposite direction.

An examination of correlation coefficients for 15 lags at the individual company level indicated that the majority of companies had very few significant coefficients. The highest number of significant coefficients - 5 - were reported by Asiri Hospitals while the next highest number of significant coefficients were documented for Ceylon Grain Elevators and Ceylinco Insurance where there were 3 significant coefficients in each instance. If we apply a decision rule of number of significant coefficients ≥ 4 (25 per cent or more) for lack of independence, the hypothesis of independence could not be rejected for all the companies except for Asiri Hospitals.

Runs Test

The results of the runs test analysis are reported in Table 4. An examination of the table reveals that the actual numbers of runs are less than the expected numbers of runs in 18 out of the 20 companies studied. Therefore, the results tend to suggest a positive persistence in share returns; a share price change tends to be followed by further changes in the same direction. When the first order serial correlation coefficient is positive indicating a certain degree of positive linear dependence, one would expect the total number of observed runs to be fewer than the total number of runs expected if the series of share price changes had been independent. The results of the runs test analysis, however, contradict with the results from the serial correlation coefficients. In Table 3, 13 out of 20 of the first-order serial correlation coefficients are negative. To be consistent with the negative dependence indicated by these 13 coefficients, the actual numbers of runs should be greater than the expected number for daily intervals of share price changes. But except for one company, Carsons Marketing, the actual numbers of runs was less than expected. However, only 8 out of the 20 companies indicated a significant difference between the actual number of runs and the expected number of runs (see columns 4 and 5 of Table 4) suggesting that only a minority of companies exhibited a statistical departure from randomness. The evidence for the majority, 12 out of 20, tended to suggest that successive share price changes are statistically random.

Table 3: Serial correlation estimates.

Security	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 10	Lag 15
Aitken Spence Hotels	-0.029	0.027	-0.042	0.014	0.011	-0.003	0.071
Asian Cotton Mills	-0.426*	-0.002	0.018	0.017	-0.073	-0.002	0.057
Asiri Hospitals	-0.203*	0.122*	-0.151*	0.053	-0.009	-0.095	-0.080
Blue Diamonds Jewel.	0.209*	0.034	0.041	-0.104	-0.016	-0.022	0.053
Carsons Marketing	-0.104	-0.002	-0.123*	0.005	-0.019	-0.084	-0.107*
Central Industries	-0.072	0.035	-0.072	-0.010	-0.043	-0.076	0.063
Ceylon Grain Elevators	-0.163*	-0.007	0.025	0.003	0.073	-0.003	0.005
Ceylinco Insurance	0.114*	-0.123*	-0.133*	0.021	0.036	0.021	-0.016
Ceylon Oxygen	-0.023	-0.503*	0.017	0.008	0.000	0.026	0.013
Compack Morrison	-0.063	0.034	-0.084	-0.043	-0.122*	0.041	-0.036
CT Land Development	0.022	-0.130*	-0.040	0.040	-0.030	0.024	0.047
Ceylon Tobacco Company	-0.006	-0.102	-0.017	0.061	0.013	0.004	-0.062
Korea Ceylon Footwear	0.019	-0.054	-0.049	0.041	0.030	-0.032	0.052
Lanka Aluminium Industries	-0.326*	-0.025	-0.047	-0.018	-0.039	0.025	0.032
Lanka Milk Foods	0.134*	-0.011	-0.134*	0.008	-0.009	-0.054	-0.028
Lanka Tiles	0.081	-0.023	-0.065	-0.062	-0.084	-0.106*	0.025
Merchant Bank of Sri Lanka	0.032	-0.041	-0.041	0.001	-0.030	-0.045	0.034
Nestle Lanka	-0.075	0.113*	-0.062	-0.051	-0.049	-0.012	-0.099
Seylan Trust Bank	-0.030	0.028	-0.085	0.016	0.065	-0.036	-0.017
United Motors	-0.034	-0.019	-0.100	0.036	-0.076	0.025	0.011
No. of Significant Coefficients	7	5	4	0	1	1	1
% of Significant Coefficients	35.00	25.00	20.00	0.00	5.00	5.00	5.00

The table reports correlation coefficients of each share for 1-15 lag intervals. Furthermore, the number of significant coefficients and the percentages of significant coefficients at each lag interval are reported in the bottom two lines of the table. An * denotes the statistical significance at 0.05 level.

Table 4: Runs test.

(1) Security	(2) No. of Runs Observed	(3) No. of Runs Expected	(4) (2)-(3)/(3)	(5) Level of Significance
Aitken Spence Hotels	122	146.48	-0.167	0.00*
Asian Cotton Mills	141	141.49	-0.004	0.95
Asiri Hospitals	133	144.86	-0.082	0.13
Blue Diamonds Jewel.	132	157.15	-0.160	0.00*
Carsons Marketing	153	147.27	0.039	0.47
Central Industries	110	134.18	-0.180	0.00*
Ceylon Grain Elevators	145	146.48	-0.010	0.85
Ceylinco Insurance	136	155.87	-0.127	0.02*
Ceylon Oxygen	127	157.15	-0.192	0.00*
Compack Morrison	127	151.78	-0.163	0.00*
CT Land Development	120	131.25	-0.086	0.11
Ceylon Tobacco Company	136	147.27	-0.077	0.15
Korea Ceylon Footwear	153	144.04	0.062	0.24
Lanka Aluminium Industries	119	132.24	-0.100	0.06
Lanka Milk Foods	137	157.15	-0.128	0.02*
Lanka Tiles	144	154.56	-0.068	0.20
Merchant Bank of Sri Lanka	115	165.65	-0.306	0.00*
Nestle Lanka	140	155.87	-0.102	0.06
Seylan Trust Bank	158	164.28	-0.038	0.47
United Motors	143	154.56	-0.075	0.16

The table reports the number of actual runs observed, the number of runs expected, the difference between the actual number of runs and the expected number of runs and the level of significance for each security. An * denotes the statistical significance at 0.05 level where the hypothesis of randomness was rejected.

Conclusion

In this study we examined whether the behaviour of the series of price changes for a sample of 20 shares quoted on the Colombo Stock Exchange were consistent with the weak-form of the EMH employing two traditional forms of statistical analysis - (a) serial correlation analysis and (b) runs test analysis. The results of the serial correlation analysis revealed that the majority of the coefficients were negative although not statistically significant. On the other hand, analysis of the runs test results suggested some evidence of positive persistence in share price changes but only 40 per cent of the securities studied showed a significant departure from randomness while the majority (60 per cent) did not reject the hypothesis of independence.

At this point it is worthwhile mentioning some possible directions for future research into share price behaviour for shares trading on the Colombo Stock Exchange. The share prices analysed in this study only spanned a short time period of 16 months; the non-availability of data for a longer time period prevented us from conducting a more comprehensive study. Furthermore, the share prices analysed in this study were unadjusted prices and the lack of detailed information regarding stock splits, dividend payments etc. prevented any adjustment to share prices for these specific events. Future research would benefit from using adjusted share price data and testing the weak-form efficiency for weekly and monthly as well as daily price data, incorporating any bid ask spread information.

Overall, based on the evidence of this study we do not categorically conclude that the CSE is weak-form efficient. The most appropriate explanation of the contradictory results may be the time span considered and the data used. Future research (based on longer time intervals of different price series and which employ a variety of advanced methodologies) are needed to draw stronger conclusions about the weak-form efficiency of the CSE. Nevertheless, this study remains one of the pioneering investigations of this area for the CSE.

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