Using daily price quotations of 93 actively traded shares for the period January 1988 to April 1990, S. K. Chaudhuri makes an attempt to examine the serial independence of share price changes. In particular, he applies the serial correlation test and the runs test to daily log price changes.

The test results, according to him, do not appear to support the hypothesis of weak form of market efficiency.

Stock market efficiency indicates how successful the market is in establishing security prices that reflect the 'worth' of the securities — success being defined as to whether the market incorporates all new information in its security prices in a rapid and unbiased manner. There are two aspects of price adjustment to new information — the 'speed' and the 'quality' of the adjustment. If the market is efficient in terms of these two aspects, then most investors will not be able to systematically outperform the market by following conventional approaches (like using charts to predict future prices or searching for 'mispriced' securities).

In literature, a distinction is made between three potential levels of efficiency—'weak' / 'semi-strong' and 'strong' — each relating to a specific set of information which is increasingly more comprehensive than the previous one. The market is efficient in the 'weak' sense if share prices fully reflect the information implied by all prior price movements. Price movements, in effect, are totally independent of earlier movements. Consequently, investors are unable to profit from studying charts of past prices. In addition, efficiency at the weak level rules out the validity of trading rules (such as 'sell a share if it falls by x% below a certain price') designed to produce above-average returns. The weak form of efficiency has also been designated in literature as 'random walk hypotheses.' In the 'semi-strong' form, the information set comprises of publicly available information. The implication of market being efficient in the semi-strong sense is that it would be rather futile for investors to search for bargain opportunities (i.e., 'mispriced' shares) from an analysis of published data. The market is efficient in the 'strong' sense if shares fully reflect not only published information, but also all relevant information including information not yet publicly available. If the market were strongly efficient, then even an insider would not be able to profit from his privileged position. Needless to say, these three levels are not independent of one another. For the market to be efficient in the strong sense, it must also be efficient at the two lower levels, otherwise the price would not capture all relevant information. Keane (1983) provides a lucid exposition of efficient market theory and related issues.
Empirical Studies

The stock market’s pricing efficiency is an issue that can be examined only by empirical research. Although the first tests of market efficiency were reported as early as 1900, the classification of efficiency into three levels did not emerge until 1959 since it was not until the fifties that research in the area developed systematically. Kuehner and Renwick (1980) provide an excellent review of empirical studies on market efficiency. In the Indian context, a few studies are available which are discussed next.

In their study (probably the first on random walk hypothesis), Rao and Mukherjee (1971) applied spectral analysis to weekly averages of daily closing quotations of just one company’s share (Indian Aluminium) for the period 1955-70, and found no evidence contrary to random walk hypothesis. Ray (1976) constructed index series for six industries as well as for all industries and tested the hypothesis of independence on these series. He obtained mixed results, though evidence was more towards rejection of the null hypothesis of independence. In another study, Sharma and Kennedy (1977), who examined monthly indices of the Bombay, New York and London Stock Exchanges during 1963-73 through runs tests and spectral analysis, concluded that "... stocks on the Bombay Stock Exchange obey a random walk and are equivalent in this sense to the behaviour of stock prices in the markets of advanced industrialized countries...." (p 411). In a more comprehensive study, Gupta (1985) tested random walk hypothesis using daily and weekly share prices of 39 shares together with the Economic Times and Financial Express indices of share prices. The study covered the period 1971-1976 and was based on serial correlation tests and runs tests. Gupta concluded that the Indian stock markets might be termed as competitive and 'weakly' efficient in pricing shares. Barua (1981) used daily closing prices of 20 shares and the Economic Times index over the two-year period 1977-1979 to confirm the efficiency of Indian stock market in its weak form.

In a more recent study, Rao (1988) examined weekend price data over the period 1982-1987 for ten blue chip companies by means of serial correlation analysis, runs tests and filter rules. He provided evidence in support of random walk hypothesis. In another study by Pandey and Bhat (1988), the attitudes and perceptions of market participants about the efficiency of the stock market were examined. The participants included preparers and users of accounting information and the survey was conducted through structured questionnaire. The respondents (160 in total) belonging to various groups (chartered accountants, academicians, investors and chief financial executives of companies) did not believe that the Indian stock market had been efficient in any of its three forms. The majority of them considered technical and fundamental analysis and audited accounting information sources to be useful in investment management.

In the above backdrop, this paper purports to present some recent findings on market efficiency in its weak form. The evidence provided here is significant in the sense that it is in sharp contradistinction with the findings of earlier studies. While we find discrete evidence in support of random walk hypothesis over the period 1971-1987, the findings of the present study, based on daily closing price quotations of 93 shares for the period January 1988 to April 1990, tend to reject it.

Research Design and Methodology

The weak form tests are concerned with the validity of using the past history of prices to predict future prices. The tests usually address two questions:

- Do prices over a period of time have sufficient serial dependence to allow investors to predict future price movements by studying trends?
- Can trading strategies based on price movements provide opportunities for abnormal profit?

The present study addresses itself only to the first question. In particular, an attempt has been made to test the null hypothesis that successive price changes are independent. Following Granger (in Elton and Gruber, 1975), the testable form of random walk model is:

\[ \ln P_t = \ln P_{t-i} + e_t \]

where \( E(e_t) = 0, \text{COV}(e_t, e_{t-s}) = 0, \text{all } s=0, \)

and \( P_t \) is the price at time \( t \) and \( e_t \) the residual series. Obviously, given this model, the price changes to be considered to test our hypothesis are given by:

\[ \ln(P_t/P_{t-i}) = e_i \]

It may be noted that based on equation (1) our test considers only the linear independence of log price changes. Furthermore, log transformation is likely to render the price changes to be homoscedastic thereby making the series stationary. One may consider simple price changes, \((P_t-P_{t-i})/P_{t-i}\) ; however, the variability of simple price changes for a given share, as observed by Moore (1964), is an increasing function of the price levels of the share. This would make the distribution of
historical price changes unstable, thus violating the assumption of stationarity of the price series.

The price data of our study consist of daily closing price quotations of 93 shares over the period January 1988 to April 1990. The choice of sample has been guided by the ready availability of price data with the author. The sample includes mostly the shares actively traded on the Bombay Stock Exchange. However, it also comprises shares listed on other major stock exchanges, namely, Calcutta, Madras and Delhi. The sample size is fairly large compared to those of earlier studies.

The price data have not been adjusted for dividends or issue of bonus/right shares. This may introduce errors in the data; nevertheless, in view of a large number of observations, errors are likely to be large enough to impair the findings of the study.

The test for the linear independence of log price changes has been carried out through the ‘serial correlation test’ and the ‘runs test.’ These tests are as follows (see Gupta, 1985):

Serial Correlation Test

The serial correlation coefficient provides a measure of relationship between the value of a random variable \(x_t\) in time \(t\) and its value \(k\)-period earlier. In the present context, it will indicate whether price changes on day \(t\) is influenced by the price changes occurring \(k\)-day earlier, where \(k = 1, 2, ..., n\). In this study, we have considered time lag of 1, 2, ..., 10 days.

The serial correlation coefficient \(r_k\) is given by

\[
(3) \quad r_k = c_k / c_0
\]

where \(c_k = \frac{1}{n} \sum_{i=1}^{n-k} (x_i - \bar{x})(x_{i+k} - \bar{x}) \quad k=0, 1, 2, \ldots
\]

and \(\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i\) and \(n\) are the mean of whole series, variance of \(x_t\) and number of observations respectively.

The test of significance of \(r_k\) (against the null hypothesis of population \(r_k\) being equal to zero) can be carried out by computing \(z\)-statistic given by

\[
Z = r_k \sqrt{n}
\]

If the estimated \(|z| \geq 1.96\), we can draw the inference that \(r_k\) is significantly different from zero at 5 per cent level, and, hence, price changes are not serially independent (or random).

Runs Test

This is a non-parametric test and is based on the analysis of runs, where a run is defined as a series of price changes of the same sign. There could be three types of runs, defined by three types of price changes—positive, zero and negative. Under the hypothesis that successive price changes are independent and on the assumption that sample proportions of positive, negative and zero (or no-price) changes are unbiased estimates of the population proportions, the expected number of runs of all types \((M)\) and the standard error \((\delta_m)\) of the expected number of runs can be obtained as:

\[
(4) \quad M = \frac{N(N+1)-\sum n_i}{2}
\]

\[
(5) \quad \delta_m = \frac{1}{N\sqrt{N-1}} \left[ \frac{3}{2} \sum_{i=1}^{3} \left( \frac{n_i^2}{N(N+1)} - 2N \sum_{i=1}^{3} n_i^2 - N^2 \right) \right]^{1/2}
\]

where \(N\) is the total number of price changes and \(n_i\) is the number of price changes of each sign.

For testing the significance of the difference between observed and expected number of runs, \(z\)-statistic can be used. It is given by

\[
z = (R+1/2-M)/\delta_m
\]

where \(R\) is the total observed number of runs of all signs and \(1/2\) is the continuity adjustment. For large \(N\), \(z\) will follow normal distribution with mean zero and variance unity. If \(|z| \geq 1.96\), null hypothesis of random price changes will be rejected.

Results and Discussion

Table 1 presents results of serial correlation tests up to a lag of 10 days for each of the sample shares. It is

<table>
<thead>
<tr>
<th>Number of Shares</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial correlation coefficient at a lag of 1 day:</td>
</tr>
<tr>
<td>Significant at 1 per cent level: 70</td>
</tr>
<tr>
<td>Significant at 5 per cent level: 2</td>
</tr>
<tr>
<td>Serial correlation coefficient at a lag of 2 days or more:</td>
</tr>
<tr>
<td>Significant at 5 per cent level: 17</td>
</tr>
</tbody>
</table>

Note: No correlation coefficient has been found to be negative.
evident from the table that the first order serial correlation coefficients are positive and mostly significant. Out of 93 sample shares, 72 shares have been found with significant correlations, suggesting thereby that the day-to-day price changes of these shares are not independent. This is in sharp contrast with the findings of earlier studies. For instance, both Gupta (1985) and Barua (1981) found first order serial correlation coefficient for individual shares to be generally small in magnitude and statistically insignificant. Even the recent study of Rao (1988) has provided evidence to suggest absence of significant correlations of week-end to week-end price changes.

While our findings do not seem to support random walk model, the magnitude of correlation coefficients is small. None of the coefficients is greater than .5. In fact, it is only in 41 per cent cases that correlations have been found to lie within the range of .4 to .5. Thus, at the most, 25 per cent of daily price changes may be explained by changes in the previous day. From the viewpoint of an investor, serial dependence of such a low order can hardly be used for predicting future course of price changes in any meaningful manner.

From Table 1 it may further be noted that most of the serial coefficients of higher order (i.e. lag in 2 days to 10 days) are not statistically significant at 5 per cent level. This would imply that beyond day-to-day price changes, share price movements are, by and large, random. There are only a couple of shares for which temporal dependence has been observed over a lag of 2 days and more; for instance, mention could be made of Atlas Copco, Indian Organic, Mahindra and Mahindra (first order correlation is not significant for this share), Telco, Bharat Forge, Goetze, Gujarat Filament and Gujarat Lyka. Even in such cases, serial correlations are quite low to be of any practical significance.

Some of our sample shares were also included in Barua's (1981) study — Bajaj Auto, Century, Escorts, GSFC, Larsen & Toubro, NOCIL, Tata Chemicals and Telco. It would be interesting to compare our findings in respect of these shares with those of Barua, though in the strict sense such a comparison may not be meaningful. It may be noted that some shares which exhibited serial dependence in price changes (of first/second order) in Barua's study have been found in our study with insignificant serial correlations, and vice-versa. For example, Bajaj Auto and Larsen & Toubro had significant correlations of first and second order respectively in Barua's study; however, our study has not revealed any significant association between day-to-day price changes for these two shares. On the other hand, while we have found price changes to exhibit serial dependence for shares like Century and Telco, Barua reported contrary findings. One implication of all these differences is that shift in market's pricing efficiency with the passage of time, when stock market itself might have undergone substantial changes in nature and volume of operations, is not an unlikely phenomenon. So, the issue of market efficiency has to be investigated with reference to a specific time period. Investors as well as analysts will be well advised not to accept market efficiency or inefficiency as a fact of economic life for all time to come.

That log price changes are mostly non-random has further been brought out by the results of runs test for individual sample shares as reported in Table 2. The standard normal variate z is significant at 5 per cent level for 63 out of 93 sample shares. There are a few shares like Asian Paints, Baroda Rayon, Britannia, Colgate, Escorts, Eskayef, etc. for which runs test results do not conform to those of serial correlation test; in most cases, however, they do.

![Table 2: Results of Runs Test (January 1988 - April 1990)](assets/table2.png)

**Conclusion**

The evidence crystallized in this study does not support the null hypothesis of serial independence of daily log price changes of individual shares. In other words, market does not seem to be efficient even in its weak form. Our serial correlation test results further suggest that no more than 25 per cent of price changes in a day may be explained by price changes on the previous day. The investors are, therefore, unlikely to benefit much by studying and utilizing the historical price data. Besides, the issue of market efficiency or inefficiency needs to be investigated through continuous research and with reference to a specific time frame. In this study, we have indicated the possibility of shift in the market's pricing efficiency with respect to individual shares. However, our findings are constrained by limited sample size and somewhat shorter length of the overall study period.
References


