

STOCK PRICE BEHAVIOUR : A SURVEY OF LITERATURE

[With Special Emphasis on
the Random walk Theory]

Dissertation Submitted to the
UNIVERSITY OF POONA
In Partial Fulfilment of the
Requirements for the
Degree of Master of Philosophy

by

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Gokhale Institute of Politics and Economics
PUNE 411 004.

AUGUST 1980

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SECTION 1

INTRODUCTION

"Securities markets exist in more than sixty countries and on all continents. They have grown in number and importance with the increase in the number and size of corporations, the volume of government debt instruments, and the diffusion of ownership of corporate and government securities.

Securities markets are organizations of security dealers and brokers whose operations reduce the cost of transferring ownership of government and corporate bonds and stocks and increase the liquidity of these assets. The reduction in transaction costs is achieved by the specialization of these organizations in transmitting information relevant for the decisions of potential buyers and sellers, by the provision of standardized contracts with respect to their purchase, sale, and financing, and frequently by furnishing specialized facilities for the execution of security transactions. Securities markets - especially organized exchanges - increase the liquidity of securities by providing almost continuous information regarding market prices, maximum bids, and minimum offers. Liquidity is increased in the sense that owners of securities can have greater knowledge of the current market value of their securities. This

reduces the risk of incorrectly assessing the value of one's securities. This increase in liquidity is important not only for holders of existing securities but also for issuers of new securities who are raising capital for their enterprises."¹

The object of the present study is to investigate the price behaviour of common stocks also called equities, and common shares. An important feature to note is that the trading in the stock market is in old issues (new issues are generally advertised and sold directly by the promoters and brokerage houses, and then they are registered in a stock exchange for trading purposes).

Two features about the stock market are noteworthy here. The first is that the stock market is similar to many other speculative markets like commodity markets, and due to this similarity many a discussion about stock price behaviour is extended to speculative price behaviour in general. The second is that we cannot regard all investors operating in the stock market as an homogeneous group, because important differences exist in the time horizons² of different investors and because while some are institutional investors trading in large blocks others are individuals trading in 'odd lots' or round lots.

Theories of Stock Price Behaviour

The stock market has been the object of study of many a person—the market professional, the teacher of finance,

the economist and the statistician—and it has given rise to many a theory of stock price behaviour. These theories can be classified under three main headings:

- a) Those based on the "Fundamental analysis" approach to security analysis or intrinsic value approach to shares and share prices.
- b) Those based on Market Analysis and Technical Analysis.
- c) Those based on the Random Walk and the Efficient Market Hypothesis (EMH).

Some of these theories are based on beliefs and past experience while others are based on strict empirical evidence. Of the three, the first two are theories held largely by market professionals while the last category is the province of academicians: the economists and the statisticians.

Theories Based on Fundamental Analysis

Under this category we can identify three approaches to stock price behaviour. These three approaches have been developed basically with a view to select stocks for investment. A typical characteristic of these approaches is that they do not bother with immediate short-term price behaviour (i.e. daily and weekly price fluctuations) but are only concerned about long term price behaviour.

- i) The oldest among them is the "anticipated market performance approach". "In this approach it is assumed that the present market price is, by and large, an appropriate

reflection of the present situation of a stock, including the general opinion of its future. But the price, say, a year from now will probably be quite different from today's though it will be appropriate for the conditions of a year hence."³ Therefore, the natural recommendation is that the security analyst should anticipate the future situation more accurately than the market (and more deeply than what is already implicit in the present market price by a detailed study) and act accordingly. When we say 'conditions in future' we mean all the conditions which effect the share price. But these are not easy to define and elaborate. Normally the economic conditions in the concerned country as well as those in the outside world effect stock prices by affecting the future of an industry or the market as a whole. Political outlook is also an important factor; further the economic viability of the companies whose stocks one is looking at is a very important thing. Besides these, much more is implicit in the words 'conditions in future' because the behaviour of the participants in the market is an important factor which is very difficult to judge and has financial as well as psychological overtones. Therefore, the job of a security analyst is not an easy one.

In the above approach when we said the analyst should anticipate future conditions more accurately than the market, the implicit assumption was that the market has not fully discounted the future situation. This assumption is also

implicit in the other two approaches in this category.⁴

ii) **Intrinsic Value Approach:** This tries to value the stock independently of the prevailing market price of the stock. The various methods of how this valuation is done are called 'valuation models'. These models are commonly used both in this approach and the next one which is also a variant of the valuation approach.

The reason why any share has future economic value is because it gives the holder of the share a right to a part of the profit of the enterprise in which the money was invested. If the investor were to hold the share for an infinite amount of time with no intention of selling, then the value is solely determined by the yield which would accrue over time which is distributed to the shareholder in the form of dividends.

Thus given a future dividend stream and some required rate of return the value of any stock can be determined by the following equation.

$$P_0 = \sum_{t=1}^{\infty} \frac{D_t}{(1+i)^t}$$

where P_0 is the intrinsic value of the stock in the year 0

D_t is the dividend expected in year t

i is the required rate of return.

The rationale behind this equation is simply that the future dividend stream has to be discounted at the required rate to

give the present value of the stock.

The above is a basic valuation model which can be modified further. Suppose the investor does not want to hold the stock for an infinite time period but wants to sell after say n , time periods. Then we also have to know the expected price at which the stock can be sold at that point of time. Let us suppose it is P_n . Then the intrinsic value of the stock is:

$$P_0 = \frac{D_1}{(1+i)^1} + \dots + \frac{D_n}{(1+i)^n} + \frac{P_n}{(1+i)^n}$$

(Where the implicit assumption is that the stock is sold after the dividend payment in the year n .)

The task of predicting the price of the stock at a future point is a difficult one. Various methods have been devised to predict the price. One method is the anticipated performance approach which we have already elaborated. Another popular method is the Price-earning multiplier approach. Price/earnings multiple i.e. P/E multiple is a function of three factors: the general market rate of interest, riskiness of the firm and growth rate of the earnings stream. If the P/E multiple of a stock has been in a certain range in the past, there is no reason to suppose it would move out of this range unless the interest rate, or riskiness or growth prospects are expected to change radically. Therefore a prediction of the earnings in future would help to decide

the price of the stock in future because the P/E multiple multiplied by the projected earnings would give a surrogate for the price at that point. (Here we should note the prediction of earnings in future is also very much necessary for predicting the future dividend stream.)

Various methods are used to predict the future dividend stream accruing from holding a stock. The first step is generally to study the past record of the concerned firm (i.e. sales, profits, dividends, cash flows, debts, assets, etc.) and then assess its future prospects. This first step necessitates an intensive study of the balance sheets, profit and loss accounts, announcements by officers of the firm, prospects of the relevant industry, etc. The next step of prediction using this knowledge is a difficult one and both naive models and sophisticated models are used. Some models just extend the past performance into future while others use methods like regression and correlation analysis, sensitivity analysis⁵ and discriminant analysis.^{6,7}

The valuation models are used in the intrinsic value approach to evaluate the intrinsic value of a share, because it is believed that there are at least some stocks which are undervalued or overvalued by the market. If this is true then the models help to find such stocks and open avenues to make profit. If some stocks which have been undervalued are found, then they should be bought and if some stocks which have been overvalued are discovered they should be sold if

they are being held or short-sold (short-sale means selling stocks which one does not own by borrowing temporarily). Obviously the rationale is that the market will ultimately realize the true value (or intrinsic value) of the stock and that the price will move towards this true value. (It should be noted that the intrinsic value of a stock is itself a changing one depending on present and future conditions.)

iii) The third approach although a member of the valuation family is concerned with relative rather than intrinsic value. This approach does not accept that intrinsic value is completely independent of the current level of stock prices and tries to estimate the relative value of the stock in terms of prevailing market level, i.e. the approach "derives the capitalization rate for an individual issue in terms of the rate at which earnings or dividends for a cross section of the market ... are being capitalized or from the capitalization rate for a specific industry".⁸

All the three approaches in one way or the other postulate that the market has not discounted the information available completely and that it will ultimately do so (i.e. the market is not fully efficient). Also it should be mentioned that all information is assumed to be freely available to one and all.

Theories Based on Technical Analysis and Market Analysis

While fundamental analysis aims at selecting good

investments and has a theory of long term stock price behaviour as a basis for its methods (valuation and anticipation), market analysis basically aims at forecasting security prices. Market analysts believe that by study of the past they are able to predict bullish and bearish trends. There are two approaches in this category. The first is technical analysis and the second is a more general approach to market analysis.

Technical Analysis

While security analysts taking the fundamental analysis approach first evaluate the true value of a stock by a study of the stock in question determining the future expected streams of dividend and the appropriate capitalization rates to be applied and then look at the prevailing market price for purposes of decision making, technical analysts start by looking at the present and past record of price data of a stock.

While the fundamental analysts use all types information in their analysis, technical analysts use only price and volume data. Technicians believe that price/volume patterns can be used to predict future and they also hypothesise that trends are persistent and so a study of the past gives indications for future.

The most famous theory in the category of technical analysis is the 'Dow Theory'. This theory was laid down by Charles H. Dow and was further elaborated by William

Hamilton.⁹ It was used successfully to predict the 1929 depression. The theory basically says that there are two types of markets movements. A Primary movement which is a long term movement of the market over a period of a few years which is either upward bullish or a downward bearish. Secondary movements also exist which are in a direction opposite to the major movement but of a shorter length. These secondary movements are the ones in which the technical analyst is interested because they being in the opposite direction to the market offer opportunities to make profit. If the technical analyst is able to predict a turning point i.e. either the start of a secondary movement or the end of a secondary movement he will be able to make a profit.

Volume is an important factor in technical analysis because turning points accompanied by a high volume of trading is said to be a stronger confirmation of a definite turn than a turn accompanied by a small volume.

Line and Bar charting is a basic tool in technical analysis and this is the reason why technical analysts are also called chartists.

Line charting is simply a plot of prices recorded at regular intervals while bar charting records both the high and low prices within an interval. In a bar chart vertical bars are used to record the prices in an interval. The top of the vertical bar shows the high, while the bottom the low

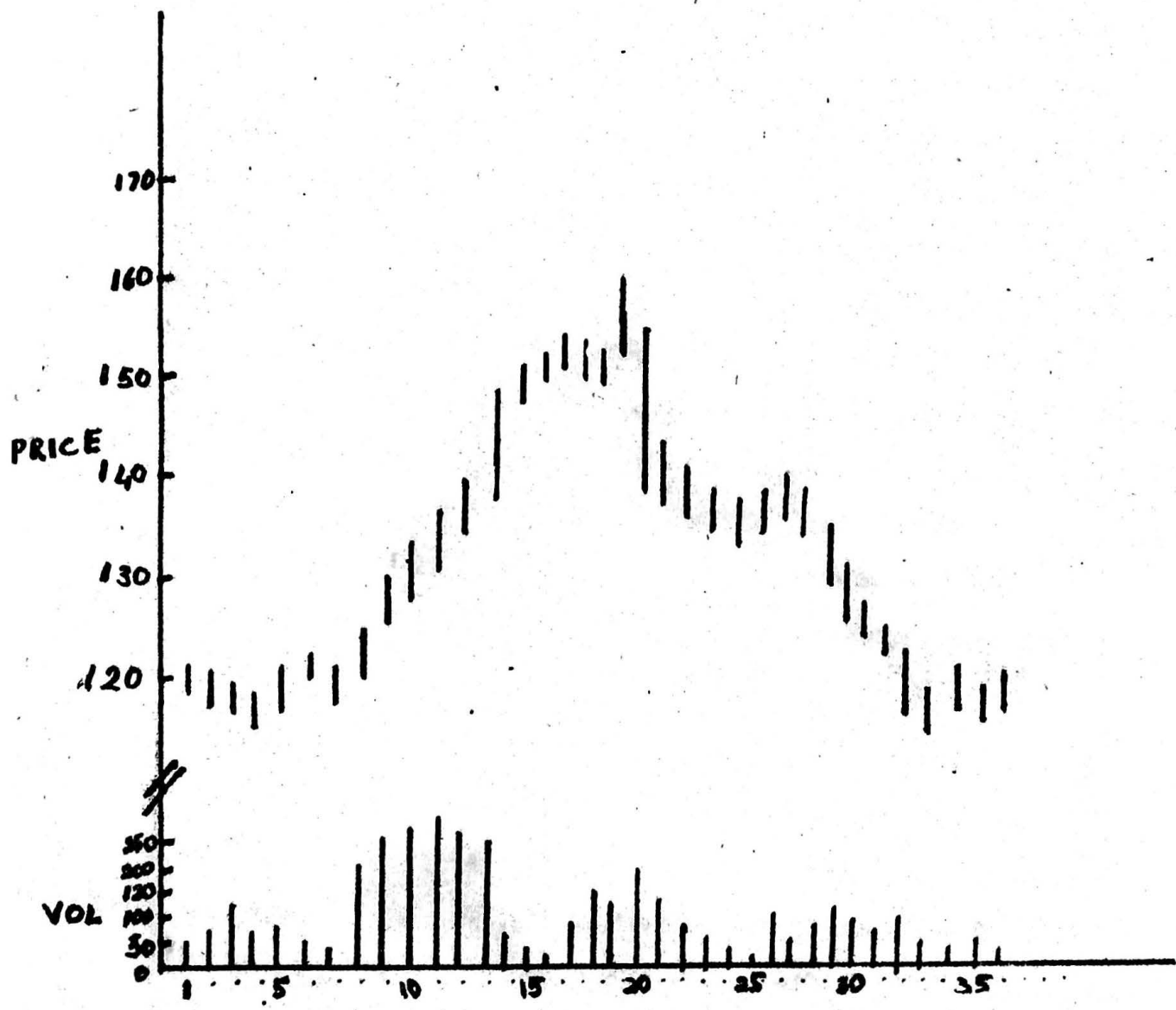


FIG. 1. A Bar Chart

price in that interval (say a day or a week). A typical bar chart is shown in Figure 1 with volume data recorded at the base of the chart. Depending on how the prices are moving they are looked at in terms of triangles and flags. For example a tight upslanting flag means that there is an upward trend in the prices. A descending triangle on the other hand would be seen as a downward movement of prices. If these upward or downward trends are accompanied by heavy trading as shown by the volume data in the chart then the trends are taken as confirmed as already mentioned. Many other predictive chart patterns besides the two mentioned above exist like saucer, bar top, wedge, (downside breakaway gap,) etc.

Point and Figure charting is a technique in which only significant changes in prices are charted. Also in this technique the price movement within a time interval is also recorded i.e. changes in the direction of price change within an interval are plotted. Like the bar chart, technicians believe that these charts also show some predictive patterns.

Besides these, moving averages are also used by technicians. This technique helps the technician to ignore daily fluctuations in prices and look at the trends.¹⁰

The basic techniques of charting and interpreting the charts are based on certain postulates of the technical analysis. A most important one is that trends are persistent in the sense that if the chart shows the beginning of a trend

(which is discovered by the use of predictive patterns discussed above) then it will continue to do so and therefore the chartists should act at the beginning of this trend. Another important postulate is that past price patterns will repeat themselves in future. This is why, technicians while studying the charts, try to relate the current price movement with some past pattern and then predict using the knowledge of what had occurred following that past pattern.

Besides the techniques of charting, technical analysis has other theories also.

The theory of 'contrary opinion' says that small investors behaviour should be studied and that the technician should act in the opposite manner. Because odd-lot purchasers are mostly small investors, the theory says, that net purchases in odd-lot trading indicates that a market peak is imminent and that a large odd-lot sell out indicates that the trough has been reached in a market decline. Besides odd lot trading, credit balances of small investors with brokers are also taken as indicators of the intentions of small investors.

The Mutual-Fund theory says that the technicians should watch the cash balance position of mutual funds. If the funds have a big cash reserve then it indicates that they will soon buy shares and when the funds have a very low cash reserve then this is taken as an indication that they may soon sell to bring the reserve to the normal level. The actions

of the funds are considered important because when they buy or sell in the market, it is believed that the price is effected in a significant way.

Thus we find that the theories grouped under technical analysis are a varied lot with common characteristic that past price behaviour is important for future prediction and that past price patterns repeat themselves.

Second Approach to Market Analysis

Technical analysis is one approach to market analysis. The second and more general approach to market analysis considers all sorts of economic factors as being relevant for prediction e.g. business conditions,—general and specific,—money rates, political outlook, etc. The followers of this approach believe that stock prices move along with other economic factors either leading them or lagging behind them and that a study of these factors helps to predict stock prices.

A common postulate of this approach is that price movements in stock market in their aggregate (as shown by various indices) are leading indicators of subsequent fluctuations in the economy as a whole. If this is true then a study of the factors affecting the economy would help the analyst to predict stock price movements on the basis of the predictions about the economy, provided the exact nature of the lag is known.

The third theory of stock price behaviour, i.e. the random walk theory will be discussed in its various forms in the next section. In conclusion to this section we should note that the theories based on security analysis and market analysis are based mostly on experience of market professionals as already mentioned and have no strict empirical basis while the random walk theory is based on wide empirical work.

Notes and References

1. J.H. Lorie, "Securities Markets," International Encyclopedia of the Social Sciences, Vol. 14, p. 136.
2. Because of the differences in time horizons, some writers divide the investors into two groups: speculators and investors.
3. B. Graham, D.L. Dodd, and S. Cottle, Security Analysis, 4th ed., McGraw-Hill Book Company, New York, 1962, p. 26.
4. We will have opportunity to discuss this point more elaborately in the section on "Strong and Semi-Strong" tests of the Efficient Market Hypothesis.
5. This method tries to find out which are the key independent variables and how sensitive final forecasted results are to changes in the values of these key variables.
6. This approach tries to find out those financial characteristics that best discriminate profitable investments from unprofitable ones.
7. This discussion was drawn from E.E. Williams, and M.C. Findlay, Investment Analysis, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1974.
8. B. Graham et al, op.cit., p. 27.
9. William Hamilton, The Stock Market Barometer, 1922.
10. This above discussion was based on: C.P. Jones, D.L. Tuttle, and C.P. Heaton, Essentials of Modern Investments, The Ronald Press Company, New York, 1977.

SECTION 2

RANDOM WALK MODEL

The Place of Random Walk Model in Efficient Market Hypothesis (EMH)

An efficient market is one in which at any moment prices fully reflect all the available information. More precisely, in case of the stock market, "an 'efficient' market is defined as a market where there are large numbers of rational, profit-maximizers actively competing with each trying to predict future market values of individual securities, and where important current information is almost freely available to all participants".¹ Competition among the market participants leads to a situation where all available information gets reflected in the price. Some of the assumptions for an efficient market may not be fully met by the stock market; in particular, "information" is not always freely available to all the participants and although there may be a large number of competitors some are far more stronger than others. But still the stock market is thought of as a fairly good approximation to an efficient market.

By saying that an efficient market is one in which prices fully reflect all available information, one is postulating a hypothesis that is extremely difficult to test.

A corollary of the efficient market hypothesis of the stock market is that stock speculation is a "fair game". A fair game is one in which the expectation of a gain or loss is zero. This is easy to see because if the market is efficient then naturally the price expected in future on the basis of currently available information by any trading system or speculator cannot be different from the market's own expectation, and therefore expected gain or loss by a speculator or of a trading system is zero which is the definition of a "fair game". We shall come back to a more detailed discussion of this point later in this dissertation.

The efficient market hypothesis has been examined and theorized at various levels, which can be differentiated according to the information set used. In its weak form the information set used is the past history of stock prices and nothing else. In the semi-strong form the effort is to see how fast the prices adjust to new information and in the strong form the effort is to examine whether there are any investor groups who have monopolistic access to information relevant for stock price changes.

The random walk model belongs to the weak form of efficient market hypothesis as the theory and the empirical testing is based on the information set of past price series alone.

The Random Walk Model

Most of the academic contributions on share price

behaviour have been in and after the late 1950s. Before this period contributions were few and far between (for example the work by Alfred Cowles² and Holbrook Working³).

The pioneering study⁴ on stock markets was by Louis Bachelier, a French mathematician, who wrote in the year 1900. The random walk model had its origin in this work. Paul Cootner commenting on Bachelier's work says "So outstanding is his work that we can say that the study of speculative prices has its moment of glory at its moment of conception".⁵

Following H.V. Roberts and M.G. Kendall we can state the random walk in terms of a 'chance' model. To quote: "... Changes in security prices behaved nearly as if they had been generated by a suitably designed roulette wheel for which each outcome was statistically independent of past history and for which relative frequencies were reasonably stable through time."⁶ This statement in a way reflects the general way in which the random walk was formulated before 1965. It stated that (i) successive changes in security prices are statistically independent, and (ii) these price changes are identically distributed (or conform to some probability distribution which is stable). Or to say the same thing differently, successive price changes are distributed independently of each other. This means that stock price changes have "no memory". The price changes behave as if they were an independent random variable, independent

of the past history of price changes.

We should also note here that this randomness implies that stock prices (not changes) behave like cumulated random numbers, a resemblance which had been noted by Holbrook Working as early as 1934.⁷

But the point which is interesting and important to note is that not all people have interpreted this independence hypothesis in the same manner. Also, opinion about the form of the 'distribution' has not remained the same but has changed with the development of the work in this area.

Independence has two different meanings depending on whether we talk about it in statistical terms or in economic terms. This ambiguity arises because we can never hope to find a time series which is characterized by perfect independence.

In statistical terms, the level of dependence has to be judged on the basis of "whether dependence in the series of successive price changes is sufficient to account for some particular property of the distribution of price changes".⁸ If the actual dependence is not significant enough then one can conclude that the series is independent.

From an economic point of view or from the point of view of the stock market trader the independence hypothesis is relevant only if the actual degree of dependence in the price series is not enough to allow use of past price changes

to predict future price changes in such a way as to increase the expected profits (that is make them greater than the profit expected from a simple random selection procedure or buy-hold policy).

Another way of stating the random walk model is:

"Price at time t = Price at time $t-1$ + Residual at time t where the residual series has zero mean and is uncorrelated with all previous terms in the residual series."

$$\text{i.e. } P_t = P_{t-1} + e_t$$

where $E[e_t] = 0$, and $\text{cov}[e_t, e_{t-s}] = 0$ for all $s \neq 0$ where P_t is the price and e_t the residual. "If this model is true it immediately follows that the best predictor of tomorrow's price is today's price or, putting it equivalently another way: price changes cannot be predicted from previous prices."⁹

Again note here that when we say $\text{cov}(e_t, e_{t-s}) = 0$ for all $s \neq 0$ we are saying that price changes (i.e. $P_t - P_{t-1} = e_t$) are linearly unrelated, (emphasis on the word linear,) but we are saying nothing about their nonlinear relationship. Granger and Morgenstern while developing the above model argue that many types of non-linear relationships get reflected as slight positive or negative correlation on linearization and so if a non-linear relationship exists while at the same time covariance is zero, then it has to be of a very special type.¹⁰

This above model of random walk is less precise and more general than the other model we considered where the

restriction was that price changes (or residuals) be not merely uncorrelated but also should be independent. Many of the early models of random walk, although stated in terms of strict independence, were empirically tested only for serial correlation and so are more general than their postulation implies.

We should also note that the above more general model does not make any distribution assumption (as has been made in the strict random walk model) beyond saying that the variance exists and is finite.

The above more general model can also be interpreted in terms of a "martingale" model, a word which we shall explain now. Benoit Mandelbrot¹¹ and Paul Samuelson¹² were the first to suggest this martingale model which is applicable to speculative prices. They show that, "under fairly general conditions, in a market that fully 'discounts' all available information prices will follow a 'martingale' which may or may not have the independence property of a pure random walk. In particular, the martingale property implies only that expected values of future prices will be independent of the values of past prices; the distributions of future prices, however, may very well depend on the values of past prices. In a martingale, though price changes may be dependent, the dependence cannot be used by the trader to increase his expected profits. A random walk is a martingale, but a martingale is not necessarily a random walk."¹³

In terms of symbols we can state the martingale as

$$E[P_t / P_{t-j}, j > 0] = P_{t-1} \quad 14$$

This shows that if the time period t is say tomorrow and $t-1$ is today (today's price known) then the expected value of tomorrow's price given all the past history of prices is today's price. Or rather the expected future value is not influenced by past values. This more general model of random walk states that $P_t = P_{t-1} + e_t$

$$\text{and } E(e_t) = 0 \quad \text{cov}(e_t, e_{t-s}) = 0 \text{ for all } s \neq 0$$

$$\text{Therefore } E(P_t) = E(P_{t-1}) + E(e_t)$$

$$E(P_t) = P_{t-1}$$

as P_{t-1} is given and $E(e_t) = 0$.

Again $\text{cov}(e_t, e_{t-s}) = 0$ (for all $s \neq 0$) ensures that all the previous price changes do not influence (linearly) the present change and therefore the present price.

Thus it is simple to interpret this more general model in terms of martingale properties. This more general model is referred to as the second order martingale and much of the empirical work in the random walk area tests this model although not explicitly stated in these terms. The reason is that much of the empirical work preceded the formulation of the martingale model.

In stating the random walk hypothesis we gave two properties of it, i.e., independence and distribution. Most

of the early work on random walk was such that the distribution of price changes or logarithm of prices was shown to be a normal distribution. But later Benoit Mandelbrot in an important article¹⁵ showed that the distribution followed by logarithm of prices was not normally distributed but followed a more general class of probability distributions called "Stable Paretian" (of which normal distribution is one).

We should also note that while some writers used and tested the random walk hypothesis with price change series, others believed that logarithm of prices were more appropriate. Paul Cootner commenting on this aspect says: "The logarithmic transformations are roughly equivalent to the proposition that stock market investors are interested in proportionate changes in the value of stocks rather than in absolute dollar values."¹⁶ Granger and Morgenstern say that although logarithmic transformation gives an impression of changing the model fundamentally, "this is not the case except at low frequencies". Low frequency changes correspond to changes during a long interval and these are usually large price changes and therefore can give rise to discrepancies between actual and log transformations. After examining this issue they conclude that "the use of the transformations is not vital when considering the predictive form of the model but it is usually of importance when the distribution of the residual terms is considered rather than their autocorrelation properties."¹⁷ The transformation is vital when con-

sidering distribution aspect because in the logarithmic form the distribution is more systematic.

The different forms of the random walk model we have discussed so far can be classified as:

1. Price changes are independent: Pure Random Walk or Strict Random Walk.
2. Price changes are uncorrelated: Second order Martingale.
3. Price changes are independent and normally distributed.
4. Price changes are independent and distributed according to Stable Paretian distribution.
5. Logarithmic prices are independent and normally distributed.

If in addition to normal distribution of logarithmic prices if we also add that standard deviation is proportional to the square root of the length of the period between price changes we have a model of stock prices following a Brownian Motion.

These models of random walk when subjected to empirical testing yielded consistent results. We shall review these empirical results in the next section.

Implications of Random Walk for Technical Analysis and Fundamental Analysis

As H.V. Roberts¹⁶ noted the random walk hypothesis is a direct challenge to the chartists or technical analysts who use the series of past prices of a stock to predict its

future behaviour.

As mentioned earlier chartist theories assume that there exists a certain dependence in the series of successive price changes and that as such it is possible to predict future price changes in a meaningful way by a study of the past. But the random walk in all its different forms predicates that the series of stock price changes has no memory, which is to say that past prices cannot be used for predicting future. According to the random walk the best possible prediction of tomorrow's price is today's price.

But it may be argued by the technical analysts that superior technical analysis using sophisticated techniques may be able to detect price trends in the stock market. This may be so on rare occasions, but if in the market there are sufficient number of superior technical analysts who are able to detect these trends, then their actions would eliminate the trend and the result would be a random walk.

But we should mention here that a random walk can also exist as a random walk with a drift (a trend) but the drift or trend is too long-term in nature to be of any real use for investors. The interpretation of a random walk with drift is that within the investors' time horizon the price changes behave as a random walk (in the more general sense of the model). If this drift is positive it is referred to as a sub-martingale.

The random walk theory, although inconsistent with the chartist theories, does not in any way hurt the 'fundamental analysis' (intrinsic value) approach to stock price behaviour.

We said an efficient market is one in which prices fully reflect all available information. By information is meant not only past prices but all other information about the stocks and the economy (like individual company prospects, future of the industry, political outlook, etc.). Prices reflect the effects of the information in two senses, in the sense of the current implications of the information as well as in the sense of the future expected events in the light of the current information.

Efficient markets give rise to random walks. This is so because when prices fully reflect available information actual prices are close to intrinsic values. But in an uncertain world all traders do not agree about the intrinsic value of a stock and as some believe that actual price is above and others that it is below the intrinsic value they trade making the actual price fluctuate about its intrinsic value. The intrinsic value of a share itself keeps on changing as new information appears in the market. Any systematic fluctuations are removed by chartists because any such trend when noted is eliminated by competition producing a random walk.

Again 'instantaneous' adjustment to new information itself results in random behaviour because sometimes actual prices overadjust to new information and sometimes they underadjust. Again there may be lags in adjustment process in the sense that the market may anticipate some information and adjust beforehand while sometimes the adjustment process is delayed.

But in all this the actual prices tend ultimately towards intrinsic values. Therefore superior fundamental analysts who are able to dig out new information before it is known to the market and act upon the information or who have abilities by which they can make more accurate projections of future results than already implicit in the market price and who are able to use it in the market will be able to make higher profits than an average investor or analyst in spite of the random walk behaviour of stock prices.

It is important to understand that the random walk theory only talks about the past price information but does not invalidate relationships posited between stock prices and other past information or future expected information like dividends, bonus share issues, etc.

We should also note that the average (as opposed to the superior) fundamental analyst cannot make profits above a simple random selection procedure as the efficient market ensures instantaneous adjustment of actual prices towards intrinsic values leaving no time for him to act. Granger

and Morgenstern state that only new information can help superior analysts as superior techniques become known over time to a larger and larger number of analysts.

The challenge posed by random walk to 'Fundamental Analysis' is rather indirect. The implication is that fundamental analysis should recognize that random walk is the result of the speedy adjustment process in an efficient market. This means that fundamental analysis should aim at finding new information before the market for better and more accurate prediction than already implicit in the market (a clear pointer that fundamental analysis by mediocre or average analysts is of no use).

Market Situations Compatible with Random Walk

Three possible market situations compatible with random walk have been studied in the literature.

The first is the one posed initially by Bachelier¹⁹ and later by M.F.M. Osborne.²⁰ They say that in a market where information is generated randomly and where uncertainty concerning intrinsic values does not follow any systematic pattern, price changes will be independent or follow a random walk.

The second possible situation is the one posed by Fama²¹ and others. Fama argues that there is no reason to rule out dependence in the information generating process or in the noise generating process (by noise is meant uncertainty

about intrinsic values). But even in such a market if there are enough number of superior technical analysts and fundamental analysts, their actions would remove all trends and any dependence in both the above processes and lead to an 'instantaneously' adjusting market which not only discounts present information but also the implications (or dependence) in present information for future events (or information). This results in the stock price changes behaving in a manner consistent with random walk.

To elaborate a little on this above feature let us suppose the dependence in the noise-generating process arises because people tend to follow some powerful traders' actions and beliefs. Suppose this trader believes that the actual price is lower than the intrinsic value and proceeds to buy, leading others in the process. If the market price was not lower than the intrinsic value, the superior analysts would immediately note the trend away from intrinsic value because of the trader's action, and their actions would break the trend if there are a sufficient number of them. Similarly, any dependence in the information-generating process when taken note of and acted by these superior analysts result in random walk behaviour of prices.

Fama argues that although the actions of the superior analysts ensure the independence of the price changes, this does not rule out the possibility of higher profits being made by them as they possess new information not yet known to the market.

By extending Fama's argument a little further, one may say that if there are enough number of superior analysts digging out new information before the market, then their actions would neutralize their excess profit-making. I feel that Fama's argument in favour of fundamental analysts is valid only if the new information found by different superior analysts is different and if they can act upon it; otherwise, they are no better off than superior chartists.

The third possible situation compatible with random walk emphasizes the role of the 'specialist'. Many academicians, writing on stock market, have studied the role of the specialist in market-making and some of them (for example Granger and Morgenstern) have shown how his actions result in the random walk behaviour of stock prices. They argue that, although dependence exists in transaction to transaction price changes, the day-to-day price changes behave like a random walk because the specialist decides on a new opening price each day (which is not the closing price of the previous trading day) after studying the new information as well as the limit orders each day.

In the later sections we shall discuss the role of the specialist and limit orders, etc., in a more elaborate way and so this point need not be elaborated beyond making a note of it here.

The task of the next section is to elaborate the empirical evidence on random walk as well as to discuss other closely related topics.

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SECTION 3

EMPIRICAL EVIDENCE ON THE RANDOM WALK THEORY AND RELATED ISSUES OF SHARE PRICE BEHAVIOUR

In this section, while presenting evidence on random walks, we shall also develop alongside some of the important techniques of testing used by writers as also the theoretical models developed by them in order to specify the exact nature of the random walk hypothesis that is being tested.

Independence

As already mentioned in the previous section, 'independence' has two meanings: statistical and financial (or economic) and the empirical testing on this aspect of random walk is concerned with both aspects. Some writers tested independence hypothesis only in its statistical sense while others tested it in both senses of the hypothesis.

Historically speaking, the Cowles-Jones¹ paper and Kendall's² paper are among the first efforts to test empirically the random walk and to present clear evidence. But the Cowles-Jones evidence had to be corrected later because of some technical mistakes in the calculations. We shall first look at Kendall's evidence and then at the Cowles-Jones evidence as corrected by Cowles.³

With a view to be systematic, we shall first discuss

the evidence on serial correlation tests and then the other evidence like runs tests, filter rules, etc. In doing so we may have to divide an author's contributions into separate parts, but we shall try to maintain a link between the different parts as far as possible.

Kendall's⁴ evidence on serial correlations tests concerns 22 price series data covering approximately the period 1928-38. Of these, 19 are British security price indices which cover different types of industrial companies - Oil, Coal, Shipping, Investment Trusts, etc. Three are commodity price series two for wheat and one for cotton. The share price series and one of the wheat price series were weekly data while the other two commodity prices relate to monthly data.

For each of the 19 share price series the first 29 serial correlations were computed. A serial correlation with say lag 10 means that the correlation between first differences of terms, 9 terms apart, is being calculated. Defining x_i as the i^{th} term of the original price series ($i=1, \dots, n$) we can define $u_{i+k} = x_{i+k+1} - x_{i+k}$. The formula used by Kendall (which is approximately the same for many other investigators) was:

$$r_k = \frac{\frac{1}{n-k} \sum_{i=1}^{n-k} u_i u_{i+k}}{\frac{1}{n} \sum_{i=1}^n u_i^2}$$

After examining the computed serial correlations Kendall concluded: "Such serial correlation as is present in this series is so weak as to dispose at once of any possibility of being able to use them for prediction. The Stock Exchange, it would appear, has a memory lasting less than a week except perhaps for Investments Trusts (Series 3), stores and catering (series 14) and all series together. It may be, of course, that series of individual share prices would behave differently; the point remains open for enquiry. But the aggregates are very slightly correlated and some of them are virtually wandering."⁵

Although Kendall's findings using share price indices give plenty of support to the random walk (especially in the second-order martingale form) and the Efficient Market hypothesis in its weak form, the paper also has one result which prompted Kendall to sound a warning against undue generalisation. For cotton price series (monthly data) the serial correlations of order one (one period lag) were found to be significant (a figure of about .340 while for other series it is about .05 or .10). However as this finding concerns commodity prices it does not affect the present exposition much except as an interesting point to note.

Following Kendall's suggestion that price averages or indices may behave differently from individual stock price series and that this needs further testing, Moore⁶ worked out the serial correlations for both the Standard and Poor's 500

Stock Index⁷ as well as for individual share price series (weekly). Moore found the serial correlation coefficient for the Standard and Poor Index very slight, but positive with a value of .068. He also formed an index of randomly selected individual stocks and similarly found slight positive serial dependence. In contrast to these results found for averages, for the individual stocks he found that although the serial correlation coefficients were small, 22 of the 30 coefficients were negative, "a result which would occur less than two times in one hundred if the price relatives were serially independent".⁸ Moore concluded that the behaviour of indices was 'detectably' different from that of 'individual price relatives'; he was however not sure whether this result could be generalised to other periods and other countries.

Moore also tried to give an explanation for the observed positive correlations in indices and negative correlations in individual share prices. The explanation was rather tentative and was based on the work by Holbrook Working⁹ and F.W. Taussig.¹⁰ Taussig's hypothesis was in terms of a penumbra or range within which prices fluctuate. The reactions of traders under uncertainty are such that they tend to act on the basis of other traders' actions and the fluctuations of prices thus generated are the result of 'consensus'. The 'consensus' is in the form of an opinion that prices outside the penumbra are uneconomic or untenable. Thus if prices fluctuate freely within the penumbra but not outside the

penumbra then this would give rise to negative dependence in the price changes.

Holbrook Working's explanation of the market behaviour was based on the fact that big price changes tend to be gradual. This gradualness, he says, results in short term predictability of the price changes. But because in the market there are some well-informed traders and some inept traders, the well-informed traders prevent the price from moving too far in one direction and this causes reversals. In Moore's opinion it is no contradiction to have negative dependence for some time periods and positive dependence for other time periods of different length which could possibly explain the negative dependence in weekly price relatives.

Moore offers a third possible explanation in terms of Osborne's¹¹ model of "resistance and support levels". Osborne finds that prices tend to cluster at even eighths i.e. $0/8$, $2/8$, $4/8$ and $6/8$ (stock prices in NYSE move in eighths i.e. say from $44-1/8$ to $44-3/8$) and he feels that this is due to a peculiar psychology of people. He says that because of this preference for people to move to even eighths, price may not change until there is enough information to bring about a movement from say $2/8$ to $4/8$ leaving out $3/8$. Thus the odd eighths act as 'miniature' resistance and support levels and this may give rise to a reduction in serial correlation of price changes.¹²

Regarding positive correlation found in price indices,

Moore says that if there are two types of information, one affecting individual stocks alone and introducing negative correlation and the other affecting the market as a whole and introducing positive correlation, then it is possible that, when the index is being formed the forces generating negative correlations get averaged out and the index shows positive correlation because of the market effect.

But as observed earlier, Moore's explanations were tentative and have to be vindicated by further evidence from testing daily and monthly data.

Sidney S. Alexander's work on serial correlations throws further light on the nature of independence in price series. Alexander before presenting his own evidence on serial correlations raises two interesting points. He observed: "Essentially, Kendall was asking with respect to each weekly series: How good is the best estimate we can make of next week's price change if we know this week's change and changes of the past twenty-nine weeks and correspondingly for the monthly series?"¹³ Alexander also points out that Kendall's findings about monthly cotton price series which show substantial correlation are due to a technical error. To quote: "Each observation of the cotton series was an average of four or five weekly observations of the corresponding month. It turns out that even if the original data—the Friday closing prices—were a random walk, with the successive first differences uncorrelated, the first differences of the monthly

average of four or five of these weekly observations would exhibit first-order serial correlations of about the magnitude Kendall found for cotton."¹⁴

After examining Kendall's data, Alexander poses an interesting question as to whether there is a long term trend as well as short-run fluctuation in the price series data, and therefore whether it is true to say that serial correlation (first order) of daily price changes is negative, of weekly changes close to zero and of monthly changes (fortnightly, two monthly, etc.) positive.

Alexander worked out the first order serial correlations for intervals of a week, 2 weeks, 4 weeks, 8 weeks and 16 weeks to test the above possibility using Kendall's data on the 19 industrial share price series. Except for an occasional high value at intervals of more than a week (possibility of which increases as the interval increases, because the number of observations dwindle), the data do not give any support to the above hypothesis and any trends, whenever they exist, are very weak. The conclusion is that the data support the random walk.

Paul Gootner¹⁵ also did work with serial correlation technique in 1962. His data were for fortyfive American companies. He found that the autocorrelation coefficients were small in general. (Gootner calls serial correlation coefficients as autocorrelation coefficients. The latter term is a much more general term as it is applicable both to time

series data as well as cross sectional data.) But Cootner found an excessive tendency for reversals or negative correlation in one week and two-week price changes. He applied the mean square successive difference test which is sensitive to this type of non-randomness. "Basically, the test is a comparison of the variance of the difference between successive one-week price changes and the variance of the price changes themselves."¹⁶ This statement refers to weekly changes and should be appropriately interpreted for other intervals. In one week price changes he found a significant tendency towards excessive reversals in the case of 14 out of 45 series. For the fourteen-week interval, 9 of the 45 series showed a tendency towards excessive continuation and 35 showed positive autocorrelation.

Fama¹⁷ also used the serial correlation technique to test the random walk hypothesis. He used daily changes in log price (logarithm of price) as the basic variable for purposes of testing and the serial correlation coefficients for, say, lag k was calculated using the following formula:

$$\frac{\text{Covariance } (u_t, u_{t-k})}{\text{Variance } (u_t)}$$

which is similar to Kendall's formula.

Fama finds that the serial correlation coefficients for daily changes in log price (of the thirty individual stocks used) are small in absolute value—about .06 in most cases. He says that dependence of such a small magnitude is, from a

practical point of view, probably unimportant for both the statistician and the investor.¹⁸ Fama also found that serial correlation coefficients for four, nine and sixteen-day changes were quite small.

Now coming to the evidence on positive and negative signs of the serial correlation coefficients: Kendall's weekly change data and Fama's daily change data give rise to a preponderance of positive signs in the coefficients. But Fama's data on four and nine day changes and Cootner's weekly change data and Moore's weekly change data (all for individual stocks) give rise to a preponderance of negative signs in the coefficients.

Cootner, while presenting his evidence, was of the opinion that the change from a tendency for excessive reversals to a tendency for excessive continuations take place smoothly as the size of the interval increases. Even if we disregard Kendall's findings because they are based on indices, Fama's findings that daily changes show a preponderance of positive coefficients is clearly contradictory to Cootner's findings. Again, as noted earlier, Moore's explanations are rather tentative and do not give us a firm basis to conclude that his findings should be correct and that other's findings are exceptions. The only saving factor in this mix of contradictory evidence is Fama's statement: "Given that the absolute size of the serial correlation coefficients is always quite small, agreement in sign among coefficients for the different

securities is not necessarily evidence for consistent pattern of dependence."¹⁹

As to why different studies give evidence of preponderance of one sign or the other, Fama observes that there is a market factor influencing all securities simultaneously and its behaviour during the period of the sample may tend to produce a preponderance of a particular sign in coefficients of the different securities although the market factors together with individual factors (individual to a firm) may produce serial independence i.e. result in small size of the coefficients.

On the whole the findings based on serial correlation technique are such that they indicate very slight or almost negligible dependence in successive price changes.

Runs Tests

This is another technique used for investigating the random walk hypothesis. If suppose a price change which is positive is given the + sign and a price change which is negative is given the - sign. Then a series of price changes can be written as something like +++-+--+ and so on. Thus a run is a sequence of one sign or the other. When a plus sign follows a plus sign (or a negative sign a negative sign) it can also be called a sequence or a continuation. When there is a change in sign then it is called a reversal.

One of the first research papers on random walks viz.

Cowles-Jones paper²⁰ used the runs test to examine the independence hypothesis. Clearly if there is some positive dependence in the series then there will be a tendency for more sequences than reversals than could be expected if the series were independent. Similarly if there is some negative dependence then there will be an excessive tendency for reversals.

The Cowles-Jones paper analysed data which included series with intervals between observations ranging from 20 minutes and an hour to 10 years (hourly, daily, weekly, monthly, etc.). The method used was to count the actual number of sequences and reversals in each series and compare it with what would be the expected number of sequences and reversals had the sample series come from a random population.

Cowles findings in the paper²¹ correcting the earlier one by Cowles-Jones were based on data of Standard and Poor Index and other price indices of a very long period of nearly a 100 years. The results showed an excessive tendency for sequences over reversals for all time intervals investigated,²² implying evidence of slight positive first order correlation in the first differences. According to Granger and Morgenstern this result was perhaps due to the fact that trend terms were not removed before the analysis, "probably biasing the result toward an extra number of sequences. The bias is similar to that which would occur if a serial correlation was estimated for a price change series without a mean being subtracted."²³

H.V. Roberts²⁴ also considered runs test as a relevant technique for testing independence in price changes. But he gave only one single example based on the Dow-Jones Industrial Index for a period of about one year in 1956. The result agrees with the independence hypothesis of random walks.

Sidney S. Alexander,²⁵ on initial examination of the distribution of runs of Standard and Poor's monthly index of share prices (for the period 1918-1956), found that the distribution of runs (distribution according to the length of the run: one week to 7 weeks) was inconsistent with the assumption of a random walk with equal probability of rise or fall. On examining the data closely he found that for the period 1918-56 the relative frequency of a rising month was 0.58 while that of a falling month was 0.42. Alexander then compared the expected runs based on relative frequencies of .57 rise and .43 fall with the observed number of runs. He also examined the findings of Cowles-Jones paper as well as those of the revised paper by Cowles. He concluded that the monthly movement of stock prices is consistent with the hypothesis of a random walk. In his view the evidence presented in the Cowles paper was spurious because of the neglect of the unequal probability of a rise and fall. Alexander's paper which also points out that there was an uptrend in prices of about 5.6 per cent per year during the period examined, besides giving evidence in support of random walks, points to a clear-cut case of share prices moving in accordance with the model of a random walk with a drift.

Fama's article of 1965²⁶ contains the most extensive and careful study of runs in price data. Unlike in the previous tests using runs, this work considers three types of price change: +, - and 0 and therefore allows for three types of runs. Fama considered the daily log price changes of thirty different U.S. companies with samples ranging from 1200 to 1700 observations. He claims that his approach to runs-testing is somewhat novel. To quote: "The differences between expected and actual number of runs will be analysed in three different ways, first by totals, then by signs, and finally by length. First, for each stock the difference between the total actual number of runs, irrespective of sign, and the total expected number will be examined. Next, the total expected and actual numbers of plus, minus, and no-change runs will be studied. Finally for runs of each sign the expected and the actual number of runs of each length will be computed."²⁷

Fama while analysing the data in the above three ways tested not only daily price differences, but also four, nine and sixteen-day price differences. In case of total expected runs test, the actual number of runs turned out to be slightly less than the expected number of runs but the percentage difference between actual and expected number of runs was quite small. Again, in case of the other two methods of runs testing, the actual results agree very closely with the expected. Fama concludes that runs testing gives little evidence of dependence in the price series considered. From

both the investors' and the statistical angle the independence hypothesis was found to be valid which shows that his findings are in conformity with the random walk.

Filter Rules

Sometimes in the literature on random walk a fear is expressed that the interrelationships among price changes are so complicated that standard statistical tools like serial correlation may not be able to detect these interrelations. It was considered, however, that financially meaningful movements may still exist which could be discovered by other methods. Sidney Alexander devised a mechanical method called filter rules and tested them empirically. He found that they resulted in profits greater than those obtained by a simple buy and hold policy (or a policy of random selection, which would give the greatest profits possible if really the price movements were a random walk).

An x per cent filter rule can be described as follows: "if the daily closing price of a security moves up at least x per cent, buy and hold the security until price moves down at least x per cent from a subsequent high, at which time simultaneously sell and go short.²⁸ The short position is maintained until the daily closing price rises at least x per cent above a subsequent low at which time one covers and buys. Moves of less than x per cent in either direction are ignored. The filter technique was suggested by Alexander to test the belief held by many market professionals that prices adjust

gradually to new information."²⁹ If we call the price change from a high to a low or a low to a high a 'move', then as the filter size is increased trading will not take place on small moves and thus losses on these small moves get eliminated; at the same time transactions dwindle in number and some moves which give gains when using a small filter result in losses with a large filter.

Using this filter rule to test the possibility of significant profits being obtained, Alexander concluded that there are trends in the stock market in terms of 'moves' not in terms of a week or a month. He observed that over time the speculative price changes seem to follow a random walk but, in terms of moves, non-randomness exists in the sense of persistence of a trend.

Benoit Mandelbrot³⁰ pointed out that there was a bias in Alexander's computations, as he used daily closing prices instead of daily highs and lows. Had daily highs and lows been used then there would have been more transactions than at daily closing prices. This is because there may be days when the daily high or low crosses the trigger point (point where transactions are triggered off) during the day but returns to within the trigger point by the close of the day. For these additional transactions the loss would be almost the full amount of the filter since the price change reversed itself during the day. But these losses may be partially compensated by larger profits on the swings enlarged by use

of daily highs and lows instead of daily closing prices. After correcting for this bias Alexander³¹ found that a filter rarely compared favourably with a simple buy and hold policy.

In the same paper Alexander goes on to test other mechanical trading methods, one of which is a simplified form of the Dow Theory. These formulae did better than both filter rules and buy and hold policy in terms of profitability and this, Alexander concluded, is evidence against the random walk hypothesis.

But after examining Alexander's second set of computations Fama³² pointed out that there was still a bias in the calculations as dividends had been ignored by Alexander; a correction for this will further reduce profits made by the mechanical trading rules. This is so because while under the buy-and-hold method the total profit obtainable is the price change plus any dividends, under a trading rule involving short sales such as filter rule, the borrower of the securities is usually required to reimburse the lender for any dividends that are paid while the short position is outstanding. And since all of Alexander's mechanical trading rules involve short sales, taking dividends into consideration may result in a situation where a buy and hold is more profitable.

Apart from Alexander, Cootner³³ also tested certain mechanical trading methods and found that these methods indicated non-randomness, but not of the order which is useful as a profitable strategy (better than buy and hold).

Fama and Blume³⁴ did an extensive study of filter rules in 1966. They observe that the study is made, because although serial correlation techniques and spectral analysis (covered later) show that the independence hypothesis of the random walk model is well supported (in the statistical sense of the term), one is not certain whether these results support the random walk hypothesis as applicable to the investors. So the study aims at testing whether a mechanical trading rule like 'filter rule' gives significant profits over and above a simple buy and hold method.

In analysing the data Fama and Blume considered different types of trading costs like commissions, brokerage fee, specialist fee and also considered the dividend factor which was neglected by Alexander.

After considering the securities individually Fama and Blume show that only four securities have positive average returns per filter after deducting commission charges. Even gross of commissions the returns were not as large as those of a simple buy and hold policy. Further Fama and Blume examined whether or not the floor trader could make a profit using filters and conclude, "if the costs of operating different versions of the filter rule are considered, it seems that even the floor trader cannot use it to increase his expected gains appreciably. Since the marginal transaction costs of the floor trader are the minimum trading costs under present institutional arrangements, our results also indicate that

the market is working rather efficiently from an economic viewpoint. In conclusion, there appears to be both positive and negative dependence in price changes. The order of magnitude of the dependence is so small, however, that our results add further to the evidence that for practical purposes the random-walk model is an adequate description of price behavior."³⁵

The above paper found positive dependence while using small filters and negative dependence while using intermediate size filters.³⁶ This is indicative a small degree of positive dependence in small price movements of very short duration and negative dependence in intermediate size price movements. These results are consistent with those reported in the sub-section on serial correlation, where we saw that there were an excessive number of positive coefficients in daily price changes and an excessive number of negative coefficients in four-and nine-day price changes. Hence "for measuring the direction and degree of dependence in price changes, the standard tools are probably as powerful as the Alexandrian filter rules."³⁷

Spectral Analysis of Price Series

The spectral analysis technique is useful for studying correlations over varying time intervals in time series data (i.e. the correlations as the interval between a pair of observations is changed) and for studying periodic variations in the series (i.e. cycles of varying length). Periodic variations are defined by the length of the period and the

amplitude (height of the variation). The frequency of variation is the reciprocal of the period. The range of frequency points used varies from zero (i.e. an infinitely long period)³⁸ to a frequency such that the period is twice the distance between successive observations in the given series (i.e. for weekly data, the period of two weeks corresponds to the highest frequency). The transformation used in spectral analysis is the transformation which defines the correspondence between the time domain and the frequency domain. Any time series may be exactly described by a sum of periodic functions and this description in terms of periodic functions may be thought of as a description which depends on the set of frequencies.

Granger and Morgenstern use a Fourier series transformation of the time series as the method of spectral analysis, as they are most interested in the contribution that some particular frequency component makes to the overall variance. They observe: "In the most general representation of the series ... no one frequency contributes any finite amount to the variance but the set of all frequencies lying in some interval will contribute a positive amount. If the frequency band $(w, w+dw)$ contributes $f(w)dw$ to the total variance, we call the function $f(w)$ the power spectrum of the series. Just as in the case of the frequency function, we are unable to estimate $f(w)$ for every w ³⁹ and therefore we have to form estimates of $f(w)$ over a set of frequency bands. A large value

of estimated $f(w)$ indicates that the frequencies of this band are of particular importance as they contribute a large amount of the total variance."⁴⁰ This means that for the length of the period corresponding to this frequency, some significant cycle exists which is distinguishable. For an independent sequence of terms (which is also called white noise) the spectrum is a horizontal line parallel to the x -axis over the complete frequency range 0 to π and for a series which is random and independent the spectrum will vary about a line parallel to the x -axis.

We should also note that spectral analysis assumes stationarity of the series (i.e. no trend in mean or variance or correlation between past and present values - underlying laws are invariant over time). This is generally not a valid assumption for economic time series, but this does not preclude the spectral techniques because it has been shown that if the underlying structure is not changing rapidly over time, spectral analysis may be used with confidence. The general method of plotting a Fourier transform of a series is to plot the frequency points on the x -axis and the log of the power spectrum of the series for the corresponding frequency on the y -axis, i.e., w on the x -axis and $f(w)$ on the y -axis.

Besides power spectrums of series, Granger and Morgenstern also use cross spectral methods while studying price series. Cross spectral methods investigate the relationship between a pair of series. A coherence-diagram shows the corre-

lations between two series for all frequencies and a phase diagram shows the lagged correlations between two series. Granger and Morgenstern observe that use of such methods allow very complex relationships to be discovered and interpreted in a useful way.

The testing was done on data transformed into log form—specifically, change in log of price (i.e. logarithmic first difference). Granger and Morgenstern justify this on both empirical and theoretical grounds and also point out that it has become a common practice. Their main reasons are: "transformed data have more symmetric and more normal histograms" and transformed data appear to be much closer to being independent observations from a random process.⁴¹

The specific model⁴² investigated was a random walk model of the following form: If x_t is a log price series, this model states that

$$x_t - x_{t-1} = e_t$$

where e_t is a serially uncorrelated random disturbance (or a white noise series). This means that the spectrum of $x_t - x_{t-1}$ will be flat over the whole frequency range 0 to π .

The data contained not only series composed of prices observed at a sequence of points of time but also series formed by averaging high and low prices during an interval. As regards possible correlation in averaged data⁴³ they argue that for averaged data, we should expect to find a downward sloping

spectrum if the underlying process is a random walk so that values near π are approximately half as large as values near zero frequency.

The data used by Granger and Morgenstern include more than fifty stock market price series. Majority of the series contain 250 to 900 observations. The series include most of the widely used indices of N.Y.S.E. (Standard and Poor, Dow Jones Industrials, SEC Stock Price Index, etc.) as well as a wide range of individual stocks of U.S. companies. The data include daily, weekly and monthly series. As to the adequacy of the data Granger and Morgenstern point out that "Experience shows that a component contributing only one thousandth of the total variance will generally be detected with series of length 250 or more."⁴⁴

Granger and Morgenstern divided the discussion of the spectra into three parts: long term or low frequency range, the wide intermediate frequency range and the very high frequency range which is concerned with changes within a day.

The findings of this rather massive empirical testing are "The spectra of the various price series which we have studied do not provide any clear indication of a refutation of the random walk model within the frequency range 0.5 cycles per year to 0.5 cycles per day. However, there is some interesting structure outside this range and there are minor effects within the range over which the process appears to be basically random walk."⁴⁵ The wide intermediate frequency

range spans the cycles from 0.5 per day to 0.5 per year. That in this range the spectra show flatness as shown in Figure 2 means that no clear trends or cycles worth noting were observed for intervals ranging from 2 days to 2 years. This clearly rules out weekly, monthly or even half-yearly dependencies in the price series. Clearly in this range the random walk is true as already mentioned.^{46,47}

Coming to the empirical evidence on cycles in the stock prices, Granger and Morgenstern try to find out whether the various seasonal and yearly cycles which are believed to exist (such as Summer high and New Year high) are true. They say that spectral techniques in general gave no evidence of an annual peak in the spectra, although small peaks corresponding to seasonal cycles (4, 3, 2.5 months) were frequently observed. Also some indices showed a three-month cycle and some weekly series showed a small monthly cycle. But none of them was found to be statistically significant in any particular spectral diagram and they were noticed only because they occurred in several diagrams. Granger and Morgenstern also state that none of the cycles is financially significant. They suggest that it is probable that because these minor cycles are financially insignificant, they have not been removed due to trading and competition.

From the foregoing we may conclude that the random walk hypothesis in the general form is well supported by evidence based on daily, weekly, monthly and yearly price changes. As

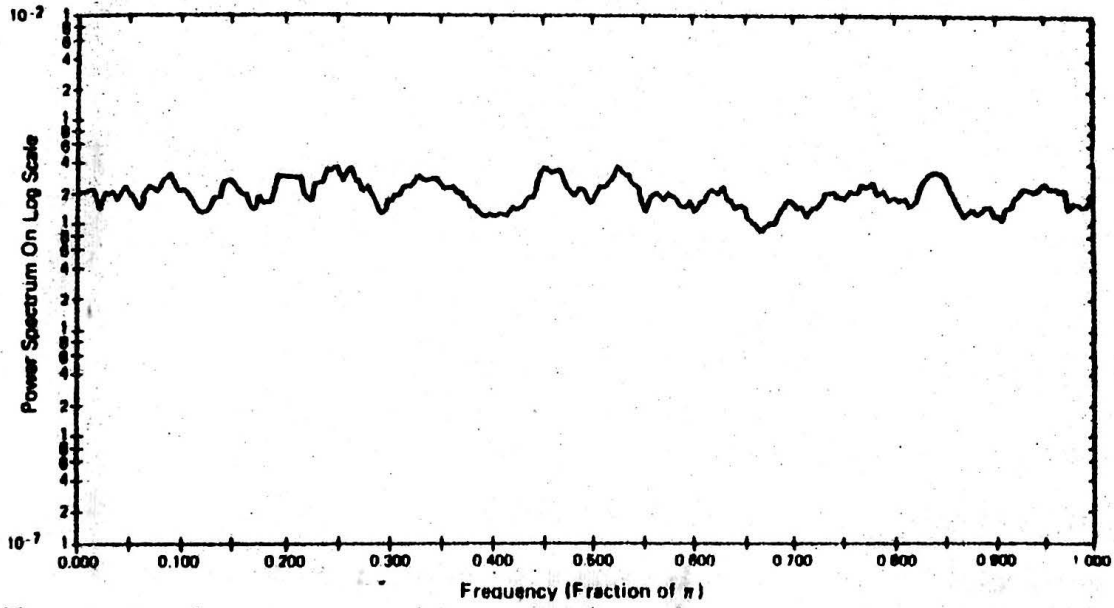


FIG. 2-A SPECTRUM OF FIRST DIFFERENCES OF A WEEKLY PRICE SERIES

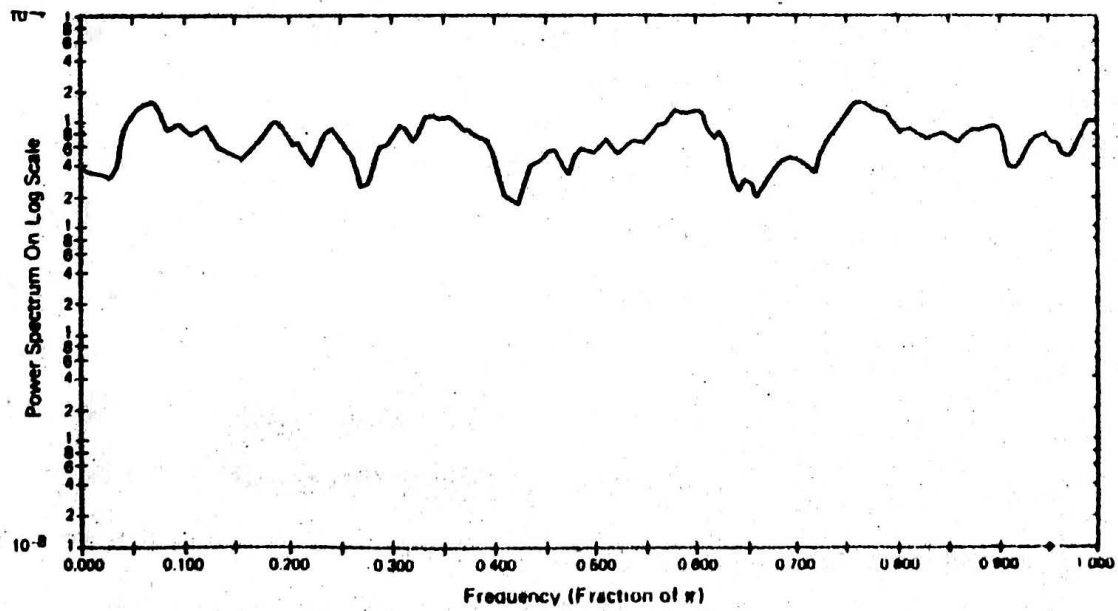


FIG 2-B SPECTRUM OF FIRST DIFFERENCES OF A
DAILY PRICE SERIES

these are the only types of changes that interest the normal investor we may say that the weak form of the efficient capital market theory is a reality for the normal investor, given his time horizon.⁴⁸

The Distribution of Price Changes

Simultaneously with the development and testing of the 'independence' aspect of random walk hypothesis, testing and refinement of the 'distribution' aspect was in progress.

In this area again Kendall's⁴⁹ paper was the first to provide evidence that the distribution of price changes was symmetric and an approximately normal. Kendall finds that the distributions of wheat price changes are leptokurtic, those of Industrial share price series (first differences) are not. He also reports that the general picture of symmetry and normality is true for many of the share price series. To quote Kendall: "At first sight the implications of these results are disturbing. If the series is homogeneous, it seems that the change in price from one week to the next is practically independent of the change from that week to the week after. This alone is enough to show that it is impossible to predict price from week to week from the series itself. And if the series is wandering, any systematic movements such as trends or cycles which may be 'observed' in such series are illusory. The series looks like a 'wandering' one, almost as if once a week the Demon of Chance drew a random number from a symmetrical population of fixed dispersion and added it to

the current price to determine the next week's price."⁵⁰

Empirical investigations by Osborne⁵¹ showed that changes in log prices ($\Delta \log_e P$) have a near normal distribution. To explain this feature he developed a model of stock price behaviour. First, he observes that the 'Weber-Fechner Law' is applicable to stock prices. This law states that equal ratios of physical stimulus corresponds to equal intervals of subjective sensation. In stock market among the various factors that influence the investor's fortunes and his expectations of profit, price is recognized to be the primary factor while dividends, earnings, etc., are secondary in nature. Thus if we agree that price is the primary stimulus affecting the profit expectations then the above law when modified to apply to the stock market implies that to the stock market trader proportionate price changes and not the absolute level of prices are of significance (for the purpose of forming profit expectations). Hence log price (i.e. $\Delta \log_e P$ or log of price ratio) is the relevant variable when looking at the stock market.

The next step taken by Osborne in building the model, was to provide the rationale behind transactions in the stock market. If we define a logical decision as one which aims at maximizing the expected value of the end result (using the given information, estimates of probabilities of the different outcomes, etc.), then the decisions of buyers and sellers to transact at certain prices must be taken as an indication that

the buyer's estimate of the expected value for change in price of the stock is positive while for the seller it is negative. Given that both buyers and sellers have equal opportunity to participate in the market "the most probable condition under which a transaction is consummated, and a price or decision is recorded, is obtained when these two estimates are equal and opposite or

$$EE(\Delta \log_e P)_S + EE(\Delta \log_e P)_B = 0$$

where P denotes price per share, and EE the estimate of the expectation value (and S and B the seller and the buyer). "Hence we can say that for the market as a whole, consisting of buyers and sellers

$$EE(\Delta \log_e P)_{M=B+S} = 0$$

is a condition under which transactions are most probably recorded."⁵² In other words the participants in the market are unlikely to trade unless there is equality of opportunity to profit, whether a person happens to be a buyer or a seller at the moment.

Under the above conditions each transaction can be viewed as an independent entity, because each transaction is the result of equal and opposite estimates by the buyer and the seller made on the basis of available information which is itself changing rapidly and randomly from time to time. If prices are recorded at equal intervals of time, then the price change during the interval is the result of a sequence of transactions occurring during the interval. These changes in

price, specifically $Y(r) = \log_e [P(t+r)/P_0(t)]$ over time intervals were shown to follow a normal distribution with the standard deviation of $Y(r)$ proportional to the square root of the time interval 'r' (i.e. $\sigma_{Y(r)} \sim \sigma\sqrt{r}$ where σ is the dispersion at the end of unit time). In coming to the above conclusion, Osborne uses the central limit theorem which assures that whatever may be the distribution function of the price change between any two consecutive transactions, the compounding of sequences of such changes occurring during a time interval will yield a normal distribution (for large number of changes).⁵³

Osborne tested the above model on the Cowles data relating to NYSE with necessary corrections. The data were in the form of an ensemble of price changes i.e. there were price indices with number of stocks used to obtain them varying from 8 to 18. Osborne concludes: "Our discussion of the equality of the estimated expectation values for buyers and sellers, for $Y = \Delta \log_e P$ led us to believe the dispersion for Y should increase as the square root of the time interval. This was amply confirmed by the data."⁵⁴

Alexander commenting on Osborne's study and its relation to the earlier one by Bachelier, observes that the standard deviation of price differences being proportional to the square root of the differencing interval is a characteristic of a random walk and that this fact had already been pointed out by Bachelier who had worked with arithmetic

differences rather than with logarithmic. Alexander also pointed out that while Bachelier derived the theoretical properties of distribution of changes in prices of commodity futures on the assumption of a 'fair game', (i.e. zero expectation of gain; because price changes in either direction of equal magnitude are equally likely), Osborne assumed that a change in either direction of a given amount in the logarithm of price was equally likely, which is no longer a fair game.

Alexander⁵⁵ criticized Osborne's paper on three counts. First, Osborne chose the proportional change model, which allows the use of a combination of different stocks with different prices levels (say one share with price 100 and another with 10), as he tried to fit a single distribution function to an ensemble of prices, and as an absolute price change model applied to a combination of different stocks with different prices would make no sense. One drawback of the proportional change model is that it allows for investment value to grow independent of inflationary effects in the economy. According to Alexander this can be avoided by adopting other models, for example, a percentage change model.

Secondly, Alexander says that by applying the Chi-square test to Osborne's data one gets results showing leptokurtosis.

Thirdly, Alexander observes: "Osborne, at best, merely showed that stock price changes might, to a rough approximation,

have been generated by a random walk type of model. He suggests conditions that are sufficient to generate the observations, but not necessary. In plain language he has a scheme which could have generated his observations; maybe it did and maybe it didn't."⁵⁶

It should be pointed out that in the above quote Alexander attacks the theoretical construct of Osborne and suggests a more rigorous formulation. However well founded the criticism by Alexander, writers upto the present time still work with logarithm of price models. Regarding Alexander's evidence of leptokurtosis in Osborne's data, it is possible that Alexander is correct in his criticism of Osborne on this account, because later writers found evidence of leptokurtosis in stock price data, a fact which led to a number of studies in this area.

Fama⁵⁷ in his 1963 article while pointing out that the work of Bachelier and Osborne are the best known theoretical expositions of the Gaussian (or normal) hypothesis, also says that empirical evidence in support of the Gaussian hypothesis has been offered by Kendall and Moore.⁵⁸ Fama further adds that Moore reported results in support of approximate normality for the weekly changes in logarithm of price of a sample of stocks drawn from the New York Stock Exchange.

According to Mandelbrot⁵⁹ 'leptokurtosis'⁶⁰ was frequently found in empirical distributions of price changes but was ignored and conclusions in favour of normality were drawn.

He says that the 'Brownian motion' hypothesis "does not account for the abundant data accumulated since 1900 by empirical economists, simply because the empirical distributions of price changes are usually too 'peaked' to be relative to samples from Gaussian populations".⁶¹

Mandelbrot, therefore, suggests a new approach to random walks (other than the normal distribution approach). This new approach which we may call the Stable Paretian hypothesis has two aspects: "(1) variances of empirical distributions behave as if they were infinite and (2) the empirical distributions conform best to the non-Gaussian members of a family of limiting distributions which Mandelbrot has called stable Paretian".⁶²

Stable⁶³ Paretian distributions have four parameters, α , β , δ , and γ . δ is the location parameter and when α is more than one, δ is the mean of the distribution. γ is the scale parameter, and β is an index of skewness. β can take any value between +1 and -1 and when it is zero the distribution is symmetric. α is the most important parameter for purposes of finding out whether Gaussian or stable Paretian hypothesis is a better fit for the data. α "determines the height of, or total probability contained in the extreme tails of the distribution, and can take any value in the interval $0 < \alpha \leq 2$. When $\alpha = 2$ the relevant stable Paretian distribution is the normal distribution."⁶⁴ But when α is between 0 and 2, the extreme tails of the stable Paretian distribution are higher

than in case of normal distributions and the probability contained in tails is also higher, and this keeps increasing as α approaches 0. The important thing to note here is that variance exists only when $\alpha = 2$ and is infinite in all other cases. But as long as $\alpha > 1$ the mean exists.

Thus the whole argument raised by Mandelbrot revolves around the value of α for the distributions of speculative prices. But estimating the value of α is not a simple task as density functions are unknown except in three cases, the Gaussian ($\alpha = 2$), the Cauchy ($\alpha = 1, \beta = 0$) and the coin-tossing case ($\alpha = \frac{1}{2}, \beta = 1, \delta = 0$ and $\gamma = 1$).

Making use of the double log graphing technique on cotton price data Mandelbrot concluded that the cotton price changes followed the stable Paretian law with $\delta = 0, \alpha = 1.7$ and $\beta = 0$ and thus uphold the stable Paretian hypothesis.

For our discussion we may point that the stable Paretian distributions have three important properties. The first is the asymptotically Paretian nature of the extreme tail areas, i.e. "tails of stable Paretian distributions for values of α less than 2 follow a weak or asymptotic form of the law of Pareto".⁶⁵ This property gives rise to the double log graphing technique that was used by Mandelbrot to test his hypothesis.

The second property is "stability or invariance under addition". This property implies that, "the distribution of

sums of independent, identically distributed, stable Paretian variables is itself stable Paretian and has the same form as the distribution of the individual summands".⁶⁶ From the point of view of price changes this implies that if price changes from transaction to transaction are independent, identically distributed, stable Paretian variables, then daily, weekly and monthly price changes will also follow stable Paretian distributions of the same form except for the origin and the scale. This is the reason for the appeal of the stable Paretian distribution. This property is very convenient because if we test say weekly price changes and find that they follow a stable Paretian then we can conclude that the price changes within the week must at the very least be asymptotically Paretian.

The third property of stable Paretian distributions is "the fact that these distributions are the only possible limiting distributions for sums of independent, identically distributed, random variables".⁶⁷

What is the nature of a market which gives rise to monthly or weekly price changes which follow a stable Paretian distribution? Following our above reasoning the price changes between transactions should then be at least asymptotically Paretian. But price changes between transactions are the result of the combined effect of bits of new information. This means that the economic conditions generating these bits of information should themselves have a stable Paretian character.

This implies that the economic conditions are subject to abrupt large changes. This again implies that stable Paretian market is much more risky for the investor than a Gaussian market. In such a market, probability of large losses are higher and variability of expected return is also more.

Mandelbrot's important conclusion is that in such a market which is subject to abrupt large changes, stop loss orders cannot protect the investor against losses because the decline in price may take place so quickly that it is impossible to carry out these orders at intermediate prices.

The stable Paretian hypothesis also has important implications for data analysis as many statistical techniques which are based on the assumption of finite variance become inappropriate or weakened if the underlying distribution followed by the data is a stable Paretian with $\alpha < 2$ which implies that variance is infinite. Some statistical tools affected by the stable Paretian hypothesis are least-squares regression technique, kurtosis (as a measure of peakedness) and the method of spectral analysis of random time series.⁶⁸

Now coming to the question of evidence in favour of the stable Paretian Hypothesis. The first impressive piece of evidence is that shown by Mandelbrot himself. In the paper by Mandelbrot mentioned above where he estimated the value of α , he conducted a direct test of the infinite variance hypothesis, using the cotton price series. On computing the

"sample second moments of the first differences of the logs of cotton prices for increasing samples of from 1 to 1300 observations" Mandelbrot found that the sample moment does not settle down to any limiting value "but rather continues to vary in absolutely erratic fashion, precisely as would be expected under his hypothesis".⁶⁹

In the work of many researchers before Mandelbrot there was evidence of high extreme tails and leptokurtosis; but all that is indirect evidence in the sense that their work did not aim at directly testing the stable Paretian hypothesis.

To find out whether the empirical distributions really were stable Paretian Fama⁷⁰ used two methods. The first method is based on the fact that if the stable Paretian hypothesis is appropriate, the extreme tails would be higher and longer than a Gaussian and would have more relative frequency contained in them.

The data used were samples of daily share price series of 30 U.S. companies with about 1200-1700 observations per sample. The sample data was for the period 1957-62. The basic variable was 'change in logarithm of price'. The data were adjusted for stock splits and dividends. Fama gives three reasons for using logarithm's of prices. He says that "(1) the change in log price is the yield, with continuous compounding, from holding the security for that day"; (2) logarithms seem to neutralize price level effect; (3) for

changes of less than 15 per cent either way the change in log price is very close to the percentage price change, "and for many purposes it is convenient to look at data in terms of percentage price changes".⁷¹

Fama concludes that for every stock the empirical distributions were more peaked in the centre and had longer tails as shown in Figure 3, than the normal distribution.

The second method used by Fama was plotting of normal probability graph for price changes of each stock. Even a casual look at these graphs plotted by Fama, show that they generally had the elongated S shape which is what one would expect with long-tailed frequency distributions. In case the distributions are normal, a straight line shape should be observed on plotting the normal probability graph.

Thus both methods of testing yielded results which indicate non-normal distribution of price changes. Fama examines two possible alternative explanations of departures from normality before accepting that the findings support the stable Paretian hypothesis. The first alternative is a mixture of distributions approach. This approach hypothesises that the distribution of price changes could be a mixture of several normal distributions thus giving rise to long tailedness. Fama's analysis of the data—week end (and after holiday changes) and daily changes (during the week)—shows that it does not make any difference whether the week end data are considered separately or are mixed with daily data; the

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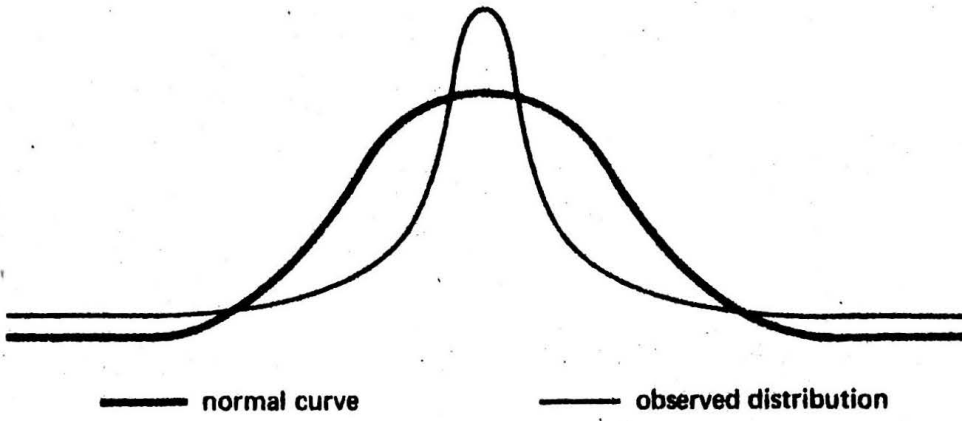


Fig. 3.

nature of tails is the same either way.

A second possibility which could explain long-tailedness is non-stationarity of the empirical distributions (i.e. it is possible that price changes at any point of time follow a normal distribution, but across time the parameters of the distribution change). A variant of the above hypothesis says that the leptokurtosis in the observed distributions is due to changes in the mean of the daily price differences across time. Empirical tests by Fama demonstrated, however, that the extreme values in the frequency distributions are so large that reasonable shifts in the mean cannot adequately explain them.

Fama also tested the stability of the empirical distributions and computed the value of the characteristic exponent α of the stable Paretian process underlying the data. He observes that lack of explicit density functions makes the task of estimating α difficult as there are no rigorously established procedures for estimation. The same three procedures as mentioned previously were used in this work also. They are double-log-normal probability graphing, sequential computation of variance and range analysis. Fama found that in a few cases α seemed to be close to 2, but in a vast majority of the cases it was less than 2, around 1.9. On the basis of these estimates of α and the findings using frequency distribution and normal probability graphs, Fama concluded that the stable Paretian hypothesis fits the data

better than the Gaussian hypothesis.

An alternative model to explain the non-normality of price changes was suggested by James Press.⁷² He says that "log prices are determined by a random walk with normally distributed changes plus a sequence of price-changing events occurring randomly in time, each contributing a random normally distributed quantity to price".⁷³

Press developed models both for a single variate case and a multivariate case. He also stated the determining parameters of the distribution (in his model) and the estimation procedures for the various parameters. He finds that although changes in log price are uncorrelated with each other, the distribution of changes differs from period to period, i.e., logged price changes do not follow some stable distribution but "follow a distribution that is a Poisson mixture of normal distributions".⁷⁴ Press argues that past evidence of empirical distributions has features which agree with the analytical characteristics of such a distribution. "That is, this distribution is in general skewed, leptokurtic, more peaked at its mean than the distribution of a comparable normal variate, and has greater probability mass in its tails than the distribution of a comparable normal variate."⁷⁵

For the univariate case Press conducted an empirical test using ten of the Dow Jones Industrial stocks for the period 1926-60, by comparing the empirical cumulative distribution function and the "estimated" theoretical cumulative

distribution function (i.e. cumulative distribution estimated from the parameters calculated assuming the log price changes follow the Poisson mixture of normal distributions). The results obtained are poor which Press attributes to the small samples used to estimate the parameters. Press observes: "In conclusion, it is expected that closer agreement with empirical distributions will be achieved in future analyses by using much larger sample sizes."⁷⁶

Granger and Morgenstern observed that Press's conclusion is possibly a biased one because evidence advanced does not support his conclusion, that the model however is still an interesting one as it is an attempt to construct a model producing a random walk "by means of reactions to sequences of unexpected events".

Although Fama has done extensive testing and found evidence in favour of the stable Paretian hypothesis, the hypothesis has not gained general acceptance mainly because, if true, standard statistical tools will have to be abandoned. For example, Granger and Morgenstern concede that the distribution (of log price changes) are long tailed but doubt whether the tails are so long that spectral techniques and regressions become useless.⁷⁷

Fama and Roll⁷⁸ did further theoretical work on symmetric stable distributions in the 70s. They constructed probability tables of the symmetric stable distributions and also developed methods for estimating various parameters. A

number of studies questioning the applicability of the stable Paretian hypothesis to stock prices were also made in the 70s, a few of which we shall briefly touch upon here.

The studies by Officer,⁷⁹ Fielitz and Smith,⁸⁰ and Hsu, Miller and Wichern⁸¹ specifically examined how well stable Paretian distributions fit to data on prices of common stocks. Officer examined the constancy of the characteristic exponent α of the distribution of stock returns through time. It was found that although the data for pre-war and post-war periods showed different values of α (estimated mean), within the post-war period the value was fairly constant ranging between 1.61 and 1.67. One of the properties of the stable Paretian distributions, we said, was that they show 'stability under addition'. This implies that if individual returns have stable Paretian distribution with a certain values for α and β , sums of returns will also have a stable Paretian distribution with the same values for α and β . This property of stability was examined by Officer in two ways: while adding returns over time (i.e. the addition of returns accruing during an interval as the interval is increased successively) and while adding across returns i.e. portfolio returns. For monthly data, although over time the stability property was true, across returns it was found that stability was not a valid property. For daily stock returns a tendency for the estimated values of α to increase for larger sums e.g. sums of 10, 15 and 20 daily returns, was found. Officer

says the reverse would be true if the stable Paretian hypothesis is true of the data. Another important finding of the study was that standard deviations of the sums of daily returns were well behaved, although we would expect them to behave erratically. Officer concludes that although the distributions of stock returns are "fat tailed" relative to normal distribution, they have some properties which are inconsistent with stable Paretian hypothesis.

The study by Fielitz and Smith uses the method of comparing for various class intervals (e.g. $\bar{x}-4\sigma$ to $\bar{x}+4\sigma$) "the mean number of observations of the empirical stock distributions with the number of observations expected to occur under a Gaussian hypothesis"⁸² to find out whether price changes follow a normal distribution or not. By recording the number of "outliers" present, they observed that the data show evidence of 'fat-tailedness', kurtosis and skewness and conclude that "stock price changes belong to the asymmetric class of members of the stable family of distributions".⁸³

Hsu, Miller and Wichern used a variant of the Chi-square goodness-of-fit test to find out whether daily rates of return of the four stocks which they examined follow stable Paretian distributions. It was found that the data are not consistent with symmetric stable distributions because the tails were too heavy and the top not peaked enough. Then the data were divided into two groups, post-war period and pre-war period. It was found that for pre-war rates of return

normality is not a valid hypothesis while for post-war rates it is valid.⁸⁴ Further testing to investigate the stability property over time showed that the underlying scale parameter was not stationary over time.

Hsu et al conclude that attempts to represent stock rates of returns by the stable Paretian hypothesis were misleading and they suggest that one should look at the rates of returns in "terms of sub-periods of homogeneous activity and that within these sub-periods, rates of return will be adequately represented by distributions with finite variance".⁸⁵

Praetz⁸⁶ in his 1972 study attempted to modify Osborne's Brownian motion hypothesis in such a way as to provide a model of distribution of share price changes. In the Osborne model there was an assumption that σ^2 , the variance of price changes over a unit time interval, is constant. The assumption in the Praetz model was that σ^2 is a random variable with distribution function $g(\sigma^2)$. This modification resulted in a scaled t-distribution. Praetz used a chi-square test to investigate which of the alternative distribution models,—normal distribution, stable Paretian distribution, compound events distribution (of Press) and scaled t-distribution,—fit the data well. It was found that the scaled t-distribution fitted the data best followed by the stable Paretian distribution. In conclusion Praetz notes that like the stable Paretian distribution, the scaled t-distribution also lies between a Cauchy and a normal distribu-

tion and so provides an alternative, with a well-developed theory, to the stable Paretian distributions.

The study by Blattberg and Gonedes⁸⁷ attempts to compare the Stable and Student t-distributions as distribution models for daily rates of return on common stocks. The models for the two distributions were derived using the framework of subordinated stochastic processes. Such a framework when applied to rates of return on common stocks can be shown as follows: Let us denote $\tilde{X}(s)$ as the rate of return over the time interval s and suppose that it is a stationary normal process. [$\tilde{X}(s)$ independent of $\tilde{X}(s^*)$ for all $s = s^*$.] Let $\tilde{h}(s)$ be a random variable which may be interpreted as a change in economic environment (or change in available information). "Before the realization of $\tilde{h}(s)$ is available, the rate of return over any interval may be written as $\tilde{Z}(s) = \tilde{X}[\tilde{h}(s)]$."⁸⁸ This implies that the process [$\tilde{Z}(s)$] is subordinate to the process [$\tilde{X}(s)$] while [$\tilde{h}(s)$] is the directing process. Using this framework Blattberg and Gonedes derived the Student-t and stable-symmetric models. The distinguishing characteristic of the models is the specification of the economic-environment i.e. the directing variable $\tilde{h}(s)$.

Blattberg and Gonedes put the two models to investigation to see which is a better model. Two methods were used: (1) a variant of the stability tests that we had discussed earlier (this test by Blattberg and Gonedes hypothesize that for Student-t distributions as the sample size increases

there is a convergence to normality while for stable distributions it is the reverse); (ii) likelihood ratio - the log-likelihood ratios allow one to determine which model has the higher likelihood, given the data.

Their conclusion is similar to the one by Praetz, that Student model has more descriptive validity than the symmetric-stable model.⁸⁹

Thus we find that the debate on the distribution of price changes has been a long and inconclusive one and further work requires to be done for obtaining a clearer picture.

Non-Cyclic Long Term Dependence

A majority of the studies on the weak form of EMH generally assumed that the price generating process was such that it had only a finite memory and therefore price changes sufficiently far removed were virtually independent. This implies that an examination of serial correlations between present and nearby past values was sufficient to draw a conclusion about the random walk or the weak form of EMH.

In the literature a number of studies were made on time series connected with climatic variables and it was found that for such series large values tend to be followed by large values of the same sign. This property was called 'persistence'. It was also found that persistence was not the result of ordinary serial dependence, but of a special

type of long term dependence with an infinite memory called "non-cyclic long run statistical dependence". "... economic time series tend to be characterised by the presence of clear-cut but not periodic 'cycles' of all conceivable 'periods', short, medium and long. ...".⁹⁰

Mandelbrot in 1971 published a study⁹¹ in which he discussed the possibility of the above type of long term dependence while examining the behaviour of arbitrated prices. In this study Mandelbrot before coming to the question of long term dependence first shows that a necessary and sufficient condition for the existence of an arbitrated price is that as the time lag increases, the strength of statistical dependence between the unarbitrated prices should decrease rapidly [i.e. if $P_0(t)$ and $P_0(t+s)$ are unarbitrated prices, the statistical dependence should decay rapidly as lag 's' increases]. In terms of the stock market this means that if the market prices of a share are arbitrated prices (in the sense that the prices fully reflect all information because any new information is immediately arbitrated away) then a necessary and sufficient condition for their existence is that as the time lag increases, the dependence between the corresponding intrinsic values should rapidly decrease, a situation which is possible only if the information influencing the intrinsic value of a share at different points of time is independent or nearly so. It was argued that unless the statistical dependence decreases rapidly, arbitraging would

not lead to prices which follow a martingale process,⁹² because changes in arbitrated prices remain correlated.⁹³ It follows that long term dependence of the type described above should be absent (besides serial correlation being absent) in the arbitrated prices for them to follow a martingale. We have already said in a previous section that martingale's and random walks are closely related. Therefore any empirical test on the above type of dependence vindicates or goes against the EMH in its weak form.

In the same study Mandelbrot also says that if 'persistent' statistical dependence is present in the un-arbitrated prices, then the arbitrated price changes exhibit the property of infinite variance.⁹⁴ Thus Mandelbrot relates the infinite variance syndrome (discussed in his earlier work on stable Paretian hypothesis) with long term statistical dependence.

Greene and Fielitz⁹⁵ made an investigation on the question of non-cyclic long term dependence in common stock returns⁹⁶ in a study in 1977. They used a technique called R/S analysis which is capable of detecting long term dependence in time series even under the infinite variance syndrome.⁹⁷ They applied the R/S test to 200 daily common stock return series. They found that there was long term dependence in the series examined and that in a majority of the series the long term dependence was positive in nature. But the series were unaffected by short term serial correlation. On further

empirical investigation using a 'Range' analysis they found that the data support the stable Paretian hypothesis rather than the Gaussian.

Although the investigation by Greene and Fielitz showed that there exists long term dependence in price series (or returns), it did not show that the dependence was such that could be exploited by investors to increase their profits. The results of the study are inconclusive because: (i) although demonstration of existence of long term dependence in price change series means a rejection of the martingale model, modifications of the weak form of EMH in the late 60's allowed for long term dependence by hypothesizing that price changes should follow a sub-martingale; (ii) a rejection of the EMH in the weak form would necessitate demonstration that investors can profit by the knowledge about long term dependence besides showing that statistical dependence exists.

Short Run Price Behaviour

By short run behaviour we mean the behaviour of price within a day, i.e. hourly, transaction to transaction prices and overnight changes.

First while discussing price behaviour we should note that there is a difference between 'market time' and 'real time'. Market time is the time during which the stock market is open and trading can take place. By 'real time' we mean not only the market time but also the period during which the market is closed. Of course in these periods of non-market

time like overnight and week-end, trading cannot take place, (over the counter-trading during this period is not official in the sense that it does not go through the market) but prices of stock do not remain unchanged during this period. If a day's closing prices and the next day's opening prices are the same one can conclude that the price changes occur only during market time. But it is common for closing prices to differ from next trading day's opening prices and this clearly means that real time is the more relevant period for price changes and that the mechanism of market making is independent of whether the market is open or closed. Granger and Morgenstern found empirical evidence that the "price generating mechanism (the random walk) continues to operate while the market is closed but at a lower 'speed'".⁹⁸

Price change behaviour from transaction to transaction was examined by Neiderhoffer and Osborne⁹⁹ and also by Granger and Morgenstern. Neiderhoffer and Osborne examined the stock market ticker¹⁰⁰ prices of NYSE. They found evidence of dependence between successive transaction to transaction price changes. Their main finding was that there exists a tendency for stock price changes to reverse direction: Most of the non-zero changes in price were in the direction opposite to the preceding non-zero change. They also found that changes in opposite directions occur approximately three times as often as changes in the same direction, and that large changes tend to be followed by large changes. They also noted some

second order effects like: "A reversal is more probable after a previous reversal than after a continuation; a continuation is more probable after a previous continuation than after a reversal".¹⁰¹

Granger and Morgenstern found evidence of negative correlation between successive ticker price changes. "The actual correlations between ΔP_j and ΔP_{j-1} were -0.247 for ITT and -0.314 for Bell and Howell and are significantly non-zero. The evidence is clear that the simple random walk model does not hold for transactions data."¹⁰² Neiderhoffer and Osborne opined that the mechanics of the market lead to such behaviour of transactions prices. Granger and Morgenstern developed the arguments further and built on this basis a model of Random Walk with Barriers.

Generally in the stock market two types of orders interact during trading. These are market orders and limit orders. Market orders as the term indicates are orders to buy or sell at the prevailing market prices. A buy limit order on the other hand specifies a price at or below which the buy order is to be executed. Similarly a limit order to sell specifies the price at or above which the shares of the person who places the order may be sold. Limit orders are placed with the specialist who executes them at the appropriate price.¹⁰³ Such limit orders form barriers to the price movement because when price has a tendency to rise due to a sequence of market buy orders, a large block of sell limit

orders at the given price would result in many transactions without price change (it would take a longer time for the price to break through the barrier). If just one market sell order comes in during this sequence (of buy orders) then a reversal would take place, because the highest buy limit order on the specialists book is lower than the lowest sell limit order which was also the actual price at the previous transaction. The argument is similar for the case where a sequence of market sell orders are being executed. Thus the larger the number of limit orders the higher the chances of a reversal. Neiderhoffer and Osborne thus explain that these price barriers are the reason for reversals in the stock market ticker prices (negative correlation).

As mentioned earlier stock market prices move in $1/8^{\text{th}}$ (i.e. say from $46-3/8$ to $46-4/8$, etc.). Neiderhoffer and Osborne show that there is a tendency for limit orders to be placed at certain prices especially at zero eighths (i.e. round prices, 46, 23) and even eighths (especially halves).¹⁰⁴ If this is true then limit orders would cluster in large blocks at certain prices and act effectively as barriers. But we should note that once the barriers are broken by trading, other barriers further apart take over.

On the basis of these arguments Granger and Morgenstern constructed their model of random walk with barriers: Prices act as random walks within the barriers and prices are reflective of the barriers when they reach them (this results

in negative correlation). The model fitted the data well. Granger and Morgenstern's test for finding the presence of such barriers in daily and weekly price series led them to conclude that barriers do not exist. This is not a surprising finding because limit orders are generally placed afresh each day after the specialist quotes the opening price of the day (which as mentioned earlier was found to be different from previous closing price). This means that prices within a day, such as transaction prices, face barriers but not daily prices.

Long run Price Behaviour

The existence of a long term upward price trend for securities is revealed by many empirical studies (and is true for many countries). A commonly held belief is that the expected value of the stock prices must increase as a natural consequence of economic growth. Of course a long term upward trend in stock prices means that investors stand to profit by investing in stocks. But the real question is whether such long term price behaviour is financially significant for the investor. For investors without a long time-horizon, the existence of such upward trend is of little significance.

If such a long-term upward trend exists then a pure random walk model would not be a true description of stock price behaviour. A true description of stock price behaviour would then be a Random Walk with drift. In the more general model, i.e., the second order martingale, this correction

would result in a sub-martingale. A sub-martingale means the $E(P_t) \geq P_{t-1}$. But we should note that the drift is not substantial enough to be of significance to a large body of investors because of nature of their time horizon and as such the random walk is still applicable to them.

Granger and Morgenstern's study using spectral techniques investigated whether there are long run fluctuations in price series over time periods longer than most speculator horizons. "The evidence from the spectra ... clearly suggests that although the random walk hypothesis is extremely successful in explaining most of the spectral shape it does not adequately explain the strong long run (24 months or more) components of the series."¹⁰⁵ They also found that although there is reason to expect a relationship between stock prices and the state of the economy, the relation actually found was not at all strong. If anything, the stock market was leading. This fact, which has already been mentioned, shows that market analysis which tries to use general economic indicators for predicting future prices is not very useful.

Relationship between Different Price Series

In this part we shall discuss how prices of shares behave relative to each other and whether there are any significant common factors affecting all prices.

Osborne points out the existence of a market factor

affecting all prices, and that $Y = \Delta \log_e P$ should be expressed as "the sum of two variables nearly independent, $Y = S + M^*$, where M^* was common to all stocks at a given time, the S independent for each stock. Each of them obeyed the same diffusion law and corresponded to decisions on the value of stock, and value of money".¹⁰⁶

Kendall also tested for interrelationships between share prices. The cross-correlations between price series were worked out. Also lag correlations were worked out with lags upto the sixth day each way. Kendall observed: "The main feature of this set of correlations is the smallness of the magnitudes for the lags. There are traces of correlation in some instances but, however real, they are very slight. Thus no series acts as a 'leader' for the others. Not only is it impossible to predict a series from its own internal behaviour but it seems equally impossible to predict it from the behavior of the other prices."¹⁰⁷

Further he pointed out: "The cross correlations of order zero suggest that there is a good deal of simultaneous sympathetic movement between the series (simultaneous, that is, within the compass of a single week). They are more or less as one would expect but not always so big as a simple model of the economy would suggest. If we regard these random changes from week to week as due to exogeneous elements, we must suppose that the elements are substantially different from one series to another, albeit not independent."¹⁰⁸

Benjamin King¹⁰⁹ studied the influence of market and industry factors on stock price behaviour to detect and explain the degree of cross sectional interdependence exhibited by the set of stock price series. His technique was "factor analysis" applied to the observed covariance matrix of a monthly price change series (closing prices).

A basic and important assumption of King's study was that the stock price changes follow a random walk. King theorised that information comes in bits and pieces affecting the future anticipations which determine the price of a security. Some of this information is such that it affects the anticipations regarding many or all stocks i.e. a market-wide effect, but it does not affect all securities to the same extent. Some of this information affects the anticipations of stocks belonging to a sub-group say an industry i.e. an industry factor and some bits of information affect the anticipations concerning a single share i.e. a unique factor. On examining 63 price series of NYSE, King found that the market effect (i.e. the proportion of variance of a stock price change explained by the market factor) was of the order of about 52 per cent and hence concluded "that the typical stock has about half of its variance explained by an element of price change that affects the whole market".¹¹⁰ But King also notes that this figure varies from industry to industry; in general, he found that metals and rails are most closely associated with the market. King also estimated the

communality between a single stock and all the other 62 stocks and found an R^2 value of about .72. This roughly means that nearly 70 per cent of price movement in a stock can be explained by movements in the prices of all other stocks in the market.

King who examined the industrial grouping effect on a particular stock price i.e. the effect of various industrial indices on a particular stock price, found that the only industrial grouping that was relevant, was the group to which the stock itself belongs. He reported that if industry effects are present they cannot explain, on an average, more than 20 per cent of the variance. King also found that there was striking evidence of industry co-movement i.e. stock prices belonging to a particular industrial grouping were found to move together (after the market effect had been removed).

Granger and Morgenstern presented the results obtained by King in a clear manner using a simplified regression model.¹¹¹ To explain the market factor the regression presented was of the form:

$$D_{tj} = \alpha_j M_t + \Sigma_{tj} \quad j=1 \dots k \quad \dots (1)$$

D_{tj} - change in log price of stock j at period t

M_t - first difference of the log of the market index price series

Σ_{tj} - residual series.

King's findings regarding the market factor correspond to the value of R^2 in the above model. To explain market and industry factors the regression form is:

$$D_{tj} = \alpha_j M_t + \beta_j I_{tj} + \Sigma_{tj} \quad \dots (2)$$

where I_{tj} is the industry factor and is represented by change in log price of some Industrial price index. Then the importance of industry factor can be obtained by subtracting the value of R^2 obtained in the (2) from the value obtained in (1).

Granger and Morgenstern also analysed data using cross spectral methods to find out relationships between price indices: Durable goods, Non-durable, Transport, Service, Trade and Finance, Utilities and Mining. If X_t and Y_t are a pair of series (in the above list) then use of cross spectral methods implies a relationship expressed by the following regression equation:

$$X_t = a Y_t + e_t$$

Coherence, Phase and gain diagrams were plotted for every pair of indices. Phase diagrams were flat indicating no lagged relationship (just as Kendall had found) and the conclusion was no one series was of any predictive value for any other series. Average coherence was also calculated: This is a measure of relatedness in spectral terms. "The relationships involving the utilities and mining indices are seen to be invariably the weakest, suggesting the stocks of companies in these industries do not follow the rest of the market very closely."¹¹²

Granger and Morgenstern also investigated whether movements in other markets around the world affected any one market. Some stock exchanges close about the time other stock exchanges open and thus it is possible that information about share movements flow from one to another causing share price co-movements in stock exchanges opening later in the day. But they found that over the period studied (1961 to 1964), price indices of different markets moved independently of one another.

Granger and Morgenstern also summarized the literature on Relative price changes. The important study in this area was by R.A. Levy.¹¹³ It was found by Levy that there is a possibility of predicting relative price changes from previous changes. It was also reported by Levy that the top 10 per cent of the stocks which grew the fastest over the previous six months period do better than average in the next six months. These results concern relative price changes and not absolute price changes and so do not affect the random walk hypothesis. However if one is able to predict how the market on an average will move in future then there is some possibility of making good profits using knowledge of relative prices. But the important question is can one predict accurately the future movement of the market, time and again?

Notes and References

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3. A. Cowles, "A Revision of Previous Conclusions Regarding Stock Price Behavior," in P.H. Cootner (ed.), op.cit.
4. M.G. Kendall, op.cit.
5. Ibid
op.cit., p. 92.
6. A.B. Moore, "Some Characteristics of Changes in Common Stock Prices," in P.H. Cootner (ed.), op.cit.
7. Standard and Poor indices, Dow Jones averages: these are some of the commonly used market indicators of the New York Stock Exchange (NYSE).
8. A.B. Moore, op.cit., p. 149.
9. H. Working, "A Theory of Anticipatory Prices," American Economic Review, 1958.
10. F.W. Taussig, "Is Market Price Determinate?" Quarterly Journal of Economics, 1921.
11. M.F.M. Osborne, "Periodic Structure in Brownian Motion of Stock Prices," (article 13) in P.H. Cootner (ed.), op.cit.
12. We shall discuss these aspects again while discussing the Random Walk with barriers.
13. Sidney S. Alexander, "Price Movements in Speculative Markets: Trends or Random Walks," (article 9) in P.H. Cootner (ed.), op.cit., p. 201.
14. Ibid., p. 203. (This point was found by Sidney S. Alexander and Holbrook Working independently of each other, but Working published his result first in Econometrica, 1960 in "Note on the Correlation of First Differences of Averages in a Random Chain".)

15. P.H. Cootner, "Stock Prices: Random vs. Systematic Changes," in P.H. Cootner (ed.), op.cit.
16. Ibid., p. 240.
17. Eugene F. Fama, "Behavior of Stock-Market Prices," Journal of Business, Vol. 38, 1965.
18. Ibid., p. 70.
19. Ibid., p. 73. Emphasis in the original.
20. Op.cit.
21. Op.cit.
22. A. Cowles, op.cit., p. 136.
23. C.W.J. Granger and O. Mortenstern, Predictability of Stock Market Prices, D.C. Heath and Company, Lexington, Massachusetts, 1970, p. 81.
24. H.V. Roberts, "Stock Market 'Patterns' and Financial Analysis: Methodological Suggestions," in P.H. Cootner (ed.), op.cit., p. 15.
25. S.S. Alexander, (article 9), op.cit.
26. Eugene F. Fama, Journal of Business, 1965, op.cit.
27. Ibid., p. 75.
28. Going short or short sales means selling shares that one does not own by borrowing temporarily.
29. C.W.J. Granger and O. Morgenstern, 1970, op.cit., p. 81.
30. Benoit Mandelbrot, "Variation of Certain Speculative Prices," in P.H. Cootner (ed.), op.cit.
31. Sidney S. Alexander, "Price Movements in Speculative Markets: Trends or Random Walks, No. 2," (article 16), in P.H. Cootner (ed.), op.cit.
32. Eugene F. Fama, Journal of Business, 1965, op.cit., p.83.
33. Article in P.H. Cootner (ed.), op.cit.
34. Eugene F. Fama and M.E. Blume, "Filter Rules and Stock Market Trading," Journal of Business, Vol. 39, 1966. They examined the same data which was used earlier by Fama in his article on stock price behavior (in 1965) i.e. the data on 30 U.S. companies with 1200 to 1700 observations per sample.

35. Ibid., p. 240.
36. Ibid., p. 238. Small filters are those upto 1.5 per cent and intermediate size filter are those from 1.5 per cent to 12 per cent.
37. Ibid., p. 241.
38. But of course as the data is for a long but finite period the lowest frequency is not exactly zero but very near zero.
39. Because the data is discrete we cannot estimate $f(w)$ for every w .
40. C.W.J. Granger and O. Morgenstern, "Spectral Analysis of New York Stock Market Prices," in P.H. Cootner (ed.), op.cit., p. 167.
41. C.W.J. Granger and O. Morgenstern, 1970, op.cit., p. 108.
42. Granger and Morgenstern feel that their predictive model, like the more general form of random walk, does not require the specification of the distribution of price changes.
43. That averaging of prices in an interval leads to serial correlation in the series has been pointed out by Holbrook Working.
44. Op.cit., p. 103.
45. C.W.J. Granger and O. Morgenstern, 1970, op.cit., p. 112.
46. The findings for the high frequency range and some of the findings of the low frequency range we shall postpone to later sub-sections.
47. Similar conclusions were arrived at by them in an earlier study: M.D. Godfrey, C.W.J. Granger and O. Morgenstern, "The Random Walk Hypothesis of Stock Market Behavior," Kyklos, Vol. 17, 1964.
48. A study applying the spectral analysis technique to Indian stock price data was published in 1976: D. Ray, "Analysis of Security Prices in India," Sankhya, Series C, Vol. 38, 1976. This study examined seven share price indices which were constructed using a selected number of shares: textiles, iron and steel, transport equipment, cement, electricity, others and all industries. On applying serial correlation, runs tests and spectral techniques the study came to the conclusion that while the indices of the iron and steel and cement category followed a random walk nothing definite can be said about the others.

49. M.G. Kendall, op.cit.
50. Ibid., p. 87.
51. M.F.M. Osborne, "Brownian Motion in the Stock Market," (article 4), in P.H. Cootner (ed.), op.cit.
52. Ibid., p. 108.
53. Osborne says that the above type of distribution function of stock price changes is exactly analogous to that of a diffusion particle in Brownian motion (a concept in physics).
54. M.F.M. Osborne, op.cit., p. 123.
55. S.S. Alexander, (article 9), op.cit.
56. Ibid., p. 209.
57. Eugene F. Fama, "Mandelbrot and the Stable Paretian Hypothesis," in P.H. Cootner (ed.), op.cit.
58. We have already seen Kendall's findings, but regarding Moore's results we will not be able to present them here because the findings are from the unpublished Ph.D. dissertation of Arnold Moore, "A Statistical Analysis of Common Stock Prices".
59. Benoit Mandelbrot, "The Variation of Certain Speculative Prices," in P.H. Cootner (ed.), op.cit.
60. Leptokurtosis in the distribution of stock price changes indicates that many small (and near zero) price changes occur than under a Gaussian hypothesis, it also shows that many more large price changes occur. This means that the market is prone to sudden large price movements. To the investor this implies that there is a possibility of sudden and large gains and losses unlike the situation under a Gaussian hypothesis.
61. Benoit Mandelbrot, in P.H. Cootner (ed.), op.cit., p.307.
62. Eugene F. Fama, in P.H. Cootner (ed.), op.cit., p. 298.
63. The following exposition is based mostly on Fama's article in P.H. Cootner (ed.), op.cit., and to some extent on Mandelbrot's, op.cit.
64. Eugene F. Fama, in P.H. Cootner (ed.), op.cit., p. 299.
65. Ibid., p. 300.

66. Ibid., p. 301.
67. Ibid., p. 301.
68. But it has been shown by some writers that as long as $\alpha > 1$, estimators involving only "first powers of stable Paretian variable" are still valid i.e. have a finite expectation and it has also been shown by John Wise that serial correlation techniques are also valid in spite of the infinite variance property. John Wise, "Linear Estimators for Linear Regression Systems Having Infinite Residual Variances," unpublished paper as quoted in Eugene F. Fama, Journal of Business, 1965, op.cit.
69. Eugene F. Fama, in P.H. Cootner (ed.), op.cit., p. 305.
70. Eugene F. Fama, Journal of Business, 1965, op.cit.
71. Ibid., p. 46.
72. S. James Press, "A Compound Events Model for Security Prices," Journal of Business, Vol. 40, 1967.
73. C.W.J. Granger and O. Morgenstern, 1970, op.cit., p. 188.
74. S. James Press, op.cit., p. 317.
75. Ibid., p. 317.
76. Ibid., p. 335.
77. C.W.J. Granger and O. Morgenstern, 1970, op.cit., p. 190.
78. Eugene F. Fama and R. Roll, "Parameter Estimates for Symmetric Stable Distributions," Journal of the American Statistical Association, Vol. 66, 1971.
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79. R.R. Officer, "The Distribution of Stock Returns," Journal of the American Statistical Association, Vol. 67, 1972. (Refer footnote 96 for elaboration on the word 'returns')
80. B.D. Fielitz and E.W. Smith, "Assymmetric Stable Distributions of Stock Price Changes," Journal of the American Statistical Association, Vol. 67, 1972.
81. D.A. Hsu, R.B. Miller and D.W. Wichern, "On the Stable Paretian Behavior of Stock-Market Prices," Journal of the American Statistical Association, Vol. 69, 1974.

82. F.D. Fielitz and E.W. Smith, op.cit., p. 813.
83. Ibid., p. 814. Emphasis added.
84. A studentized range test which is sensitive to non-normal stable and other non-normal alternatives was used. This test is similar to R/S analysis which will be touched upon later.
85. D.A. Hsu et al, op.cit., p. 113.
86. P.D. Praetz, "The Distribution of Share Price Changes," Journal of Business, Vol. 45, 1972.
87. R.C. Blattberg and N.J. Gonedes, "A Comparison of the Stable and Student Distributions as Statistical Models for Stock Prices," Journal of Business, Vol. 47, 1974.
88. Ibid., p. 253.
89. For further discussion on the Student distributions as model of stock price changes, see the articles by Praetz, and Blattberg and Gonedes in Journal of Business, 1977.
90. Benoit Mandelbrot, "Statistical Methodology for Non-Periodic Cycles: From the Covariance to R/S Analysis," Annals of Economic and Social Measurement, Vol. 1, 1972, p. 260.
91. Benoit Mandelbrot, "When Can Price be Arbitraged Efficiently? A Limit to the Validity of the Random Walk and Martingale Models," Review of Economics and Statistics, Vol. 53, 1971.
92. Samuelson in his 1965 study has shown that arbitrated prices follow a martingale in the special case where there is no risk-aversion and a zero interest rate. But in case of a positive interest rate and risk-aversion the prices follow a sub-martingale process.
P.A. Samuelson, "Proof That Properly Anticipated Prices Fluctuate Randomly," Industrial Management Review, Vol. 4, 1965; also in his Collected Scientific Papers, Vol. 3, The MIT Press, Cambridge, Massachusetts.
93. Benoit Mandelbrot, Review of Economics and Statistics, 1971, op.cit., p. 227.
94. Ibid., pp. 233-235.
95. M.T. Greene and B.D. Fielitz, "Long Term Dependence in Common Stock Returns," Journal of Financial Economics, Vol. 4, 1977.

96. The terms 'returns' and 'price changes' are used interchangeably in the literature, as returns are nothing but proportionate price changes suitably adjusted for dividends and bonus issues.
97. R/S analysis uses the R/S statistic to investigate dependence. R is the sequential range and S is ordinary standard deviation. The R/S statistic takes on certain specific values depending on whether the underlying time series is an independent, autoregressive or a long term dependent process.
98. C.W.J. Granger and O. Morgenstern, 1970, op.cit., p. 125. Granger and Morgenstern devised a method of measuring 'speed' based on spectral techniques.
99. V. Neiderhoffer and M.F.M. Osborne, "Market Making and Reversal on the Stock Exchange," Journal of the American Statistical Association, Vol. 61, 1966.
100. A 'ticker' is a telegraphic instrument used in reporting stock transactions. Ticker prices and volumes are reported continuously as and when the transactions take place in the stock exchange. This type of data is not reported by all stock exchanges.
101. V. Neiderhoffer and M.F.M. Osborne, op.cit., p. 904.
102. C.W.J. Granger and O. Morgenstern, 1970, op.cit., p.153.
103. A customer's order to buy or sell at the market price is passed on to the floor broker, who approaches the specialist at the trading post and asks for a quote. The specialist after consulting his book containing the limit orders will quote the highest buy limit order and the lowest sell limit order. The former is the selling price and the latter the buying price for the broker. Then the transaction is executed.
104. This fact was discovered earlier by some writers; for example, Osborne pointed it out in his earlier article in 1942, "Periodic Structure in Brownian Motion of Stock Prices," Operations Research, Vol. 10, 1942; also given in P.H. Cootner (ed.), op.cit.
105. C.W.J. Granger and O. Morgenstern, 1970, op.cit., p. 141.
106. M.F.M. Osborne, article 4 in P.H. Cootner (ed.), op.cit., p. 123.
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108. Ibid., p. 96.
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110. Ibid., p. 151.
111. C.W.J. Granger and O. Morgenstern, 1970, op.cit., pp. 220-224.
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SECTION 4

THE EFFICIENT MARKET HYPOTHESIS— SEMI-STRONG AND STRONG FORM TESTS

An efficient market, as mentioned earlier, is a market which fully reflects all the available information at any moment. In the last section we examined the efficient market hypothesis (EMH) in its weak form. The weak form tests aimed at examining whether current market price (or prevailing price) is independent (in the practical sense) of the past sequence of prices and this was found to be generally true. This meant that if the information set is the past price record of a stock, then its prevailing market price fully discounts this information set and therefore leaves no opportunity for an investor to make a profit in excess of the expected market profit.

Semi-Strong Form Tests

Now having dealt with the past we come to new information and its relation to the share price. The semi-strong tests aim at examining how rapidly the market adjusts to new information like bonus share issues (or stock splits), earnings announcements, dividend declarations, etc. The general aim of the tests is to see whether the EMH is confirmed when the information set is new information.

The early studies on the semi-strong form of the EMH aimed at examining the behaviour of share prices to announcements of a bonus share issue. In the 60's there were two studies one by Johnson¹ and another by Fama, Fisher, Jensen and Roll² (FFJR).

Johnson's study was aimed at developing a model to test whether a significant price change occurs due to bonus share issue after controlling for fundamental factors like earnings and dividends and trends in the market. He refers to the earlier work of Barker³ wherein it was shown that the positive price movement which occurs during the time of bonus issues was due to the expectation of a declaration of higher dividends (dividend declaration normally occurs at the same time or slightly later).

Johnson's model can be expressed as:

$$\frac{\Delta P}{P_1} = c + d \frac{E_1}{P_1} + e \frac{\Delta E}{P_1} + g \frac{D_1}{P_1} + h \frac{\Delta D}{P_1} + kI_1 + m \Delta I + qS$$

where P_1 is the price of the share at the initial time i and ΔP is the change during the interval considered

E_1 is the earnings per share at time i and ΔE the change

D_1 is the dividend per share at the initial time i and ΔD the change during the interval

I_1 is the industry index at point i and ΔI is the change

and S is the (dummy) variable which is to account ^{for} of the bonus issue factor.

Johnson's aim was to observe the value of the coefficient 'q' of the variable S when the effect of E , D , and I have been controlled.

Johnson considered a period of one year dividing it into two sub-periods, the period before the bonus issue and period after it. The former was taken to be 7-1/2 months and the latter 4-1/2 months i.e. the price, dividend, etc., were calculated for the point 7-1/2 months before the issue and the point 4-1/2 months after. The reasoning was that if the bonus issue had no effect on the price then the other variables should take care of the change in price (or relative price change). The data used to test the model was from the NYSE for the year 1959.

The conclusion was that there was a significant relationship between $\frac{\Delta P}{P_1}$ and S after controlling the other variables, which shows that the information of a bonus share issue leads to a change in price or that the market adjusts to such new information. But the additional question which was not looked at by Johnson is how rapid is the adjustment - is it so fast that investors buying the stock after the announcement of bonus issue cannot profit by its public announcement. We should also note that Johnson concluded that price changes in a share are due to the announcement of the bonus issue itself and not due to the expected higher dividend which usually accompanies such an issue.

FFJR in their 1969 study tried to study the speed of adjustment of prices to bonus issues and dividends and also the type of adjustment (i.e. whether positive or negative). They find that it is usual for the rates of returns on shares

to be unusually high in the period preceding the bonus issue, and this is true for periods much in advance of any information about such an issue reaching the market. They hypothesize that the high rates of returns and the accompanying announcement of a bonus issue give confirmation to the investor that the company's share will continue to give high returns in future also. FFJR consider the question of the price adjustment also. They use a model of the following form:

$$\log_e R_{jt} = \alpha_j + \beta_j \log_e L_t + u_{jt}$$

where R_{jt} is the price relative at time t of the j th security (i.e. the sum of price and dividend in month t divided by the price in the last month which means that \log_e of R_{jt} gives the return on the security)

and L_t is the market performance factor.

The equation shows that under normal conditions, when u_{jt} has a zero expected value, there is a normal relationship between the market and the individual share. Aggregating the residuals over all the shares which announced a bonus issue, FFJR got the average residual u_m which was interpreted to be the average deviation of the returns of bonus issue stocks from their normal relationships with the market i.e.

$$u_m = \frac{\sum_{j=1}^{N_m} u_{jm}}{N_m} \quad ; \quad U_m = \sum_{k=-29}^m u_k \quad ;$$

where N refers to the numbers of stocks under consideration
 m refers to month under consideration.

Adding these u_m successively for all months before and after

the bonus issue, FFJR got the cumulative average residuals, U_m , which was interpreted as the cumulative deviation. The data for 29 months before and 29 months after the bonus issue were considered.

On analysing the data and plotting the graphs FFJR found that the average residual in the months before the bonus issue were predominantly positive which shows that these bonus issue shares performed much better than the average (as shown in Figure 4). Again, when U_m (cumulative) were plotted, they found that they rose dramatically upto the month of bonus issue and then stabilised as shown in the diagram.

FFJR also plotted these values for shares which declared an increased dividend after the bonus issue and for those that did not. Interestingly they found that for shares that did not declare an increased dividend the cumulative average residual fell to a value which is approximately the one which was prevailing five months before the bonus issue (which is the earliest time for any information about bonus issue to reach the market).

They conclude that this is because the investors, on realizing that the increased dividend is not forthcoming, act in such a way that the share (with no increased dividends) returns to its normal relationship with the market.

Regarding the possibility of making trading profits their conclusions were tentative. They observe that fragmentary evidence shows that there is no way of making profits

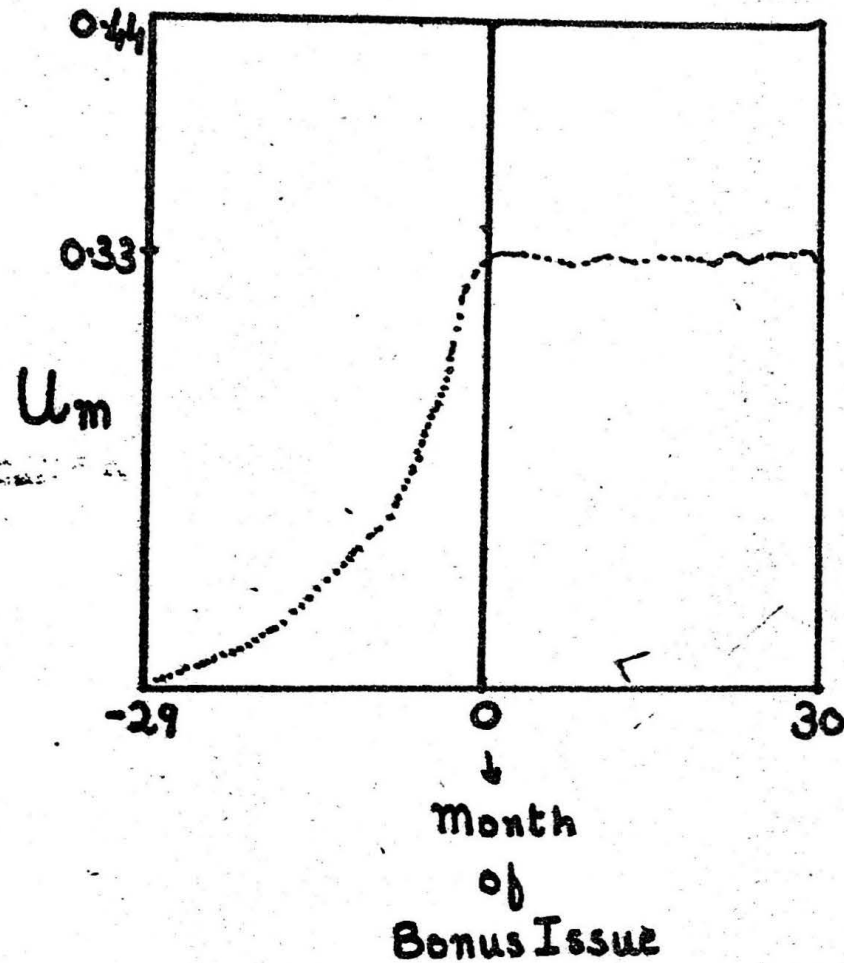
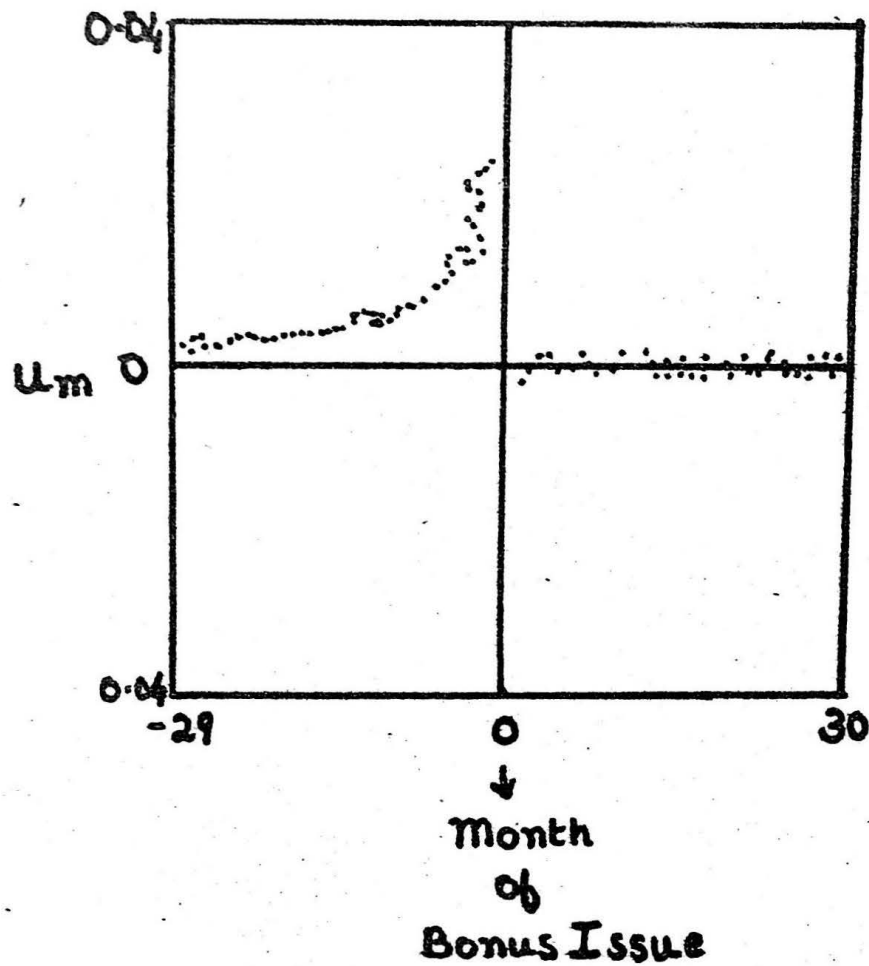


FIG. 4.

Figure showing the plot of average residuals - U_m and cumulative average residuals - U_m for the period 30 months before and after the month of bonus issue.

by acting after the bonus issue was formally announced unless of course one has prior inside information.

Hausman, West and Largay⁴ in their 1971 study examined the methods and conclusions of both FFJK and Johnson. They criticised Johnson for using only a rigid period of one year around the stock split and investigated with daily data a model similar to the one used by Johnson. They calculated the value of the coefficient of S with varying time intervals around the announcement date of the bonus issue and before and after (from 230 days prior to 135 days after). Their significant finding ^{was} ~~is~~ that as long as the interval examined contained the 28 days prior to the announcement, the value of the coefficient was significant, but not otherwise. Therefore, the conclusion was that the daily data reinforced the FFJK results and that traders cannot increase profits by acting on or after the day of the announcement of the bonus issue (the value of coefficient for the interval covering the announcement date and after was insignificant).

Another type of public announcement which has been used to test the EMH is the information about earnings per share (EPS). This information is used for valuation of equity shares and therefore the assimilation of this information by the market is important.

One of the early studies in this area is by Ball and Brown.⁵ Fama⁶ commenting on this study says: "... using data on 261 major firms for the period 1946-66, Ball and

Brown apply the method" (of residual analysis,⁷) "to study the effects of annual earnings announcements. They use the residuals from a time series regression of the annual earnings of a firm on the average earnings of all the firms to classify the firm's earnings for a given year as having "increased" or "decreased" relative to the market. Residuals from regressions of a monthly common stock returns on an index of returns ... are then used to compute cumulative average return residuals separately for the earnings that "increased", and those that "decreased". The cumulative average return residuals rise throughout the year in advance of the announcement for the earnings "increased" category, and fell for earnings "decreased" category. Ball and Brown conclude that in fact no more than about ten to fifteen per cent of the information in the annual earnings announcement has not been anticipated by the month of the announcement."⁸ Their general conclusion was that the market was efficient, and was able to anticipate and adjust to new information such as annual earnings announcements.

Jones and Litzenberger⁹ in their 1970 study come to a conclusion opposite to that in Ball and Brown study. They used quarterly earnings reports to test the efficiency of the market. First Jones and Litzenberger divided the investors into two groups: (i) those who have other occupations and (ii) market professionals. They postulated that changes in beliefs of market professionals about the intrinsic worth of

a share would cause gradual rather than instantaneous price adjustments leading to intermediate stock price trends. They say that this would be so because information about intrinsic value gets around gradually through advisory services, stock brokers, etc. Annual earnings reports were not considered so relevant as quarterly earnings reports because three-fourths of the information of the former is already contained in the latter. Thus their hypothesis boils down to saying that quarterly earnings reports, which differ from those anticipated in a significant way, cause gradual adjustments in stock prices.

The method adopted by them was as follows: A straight line was fitted to the quarterly earnings per share (for each share) for successive overlapping eight-quarter periods and using this the earnings were projected for the ninth quarter (the shares with correlation between earnings in a two-year period of more than .70 were selected). For those shares whose annual earnings were significantly different from expected, the share price movements were noted and price relatives (six-month) were calculated. These price relatives for individual stocks were compared with the price relatives for Standard and Poor Industrial Index. Using the method 211 common stocks, whose actual earnings were greater than anticipated, were examined and it was found that for 136 of them the respective price relative outperformed the Index. The obvious conclusion was that if the stock price relative (i.e. the ratio of price six months after the earnings report to price at the time of the report) exceeds that of the Index, then the stock price

adjustment was taking place gradually over the six-month period. Another interesting conclusion was that for stocks whose actual earnings were lower than expected, the adjustment of price downward was rapid and not gradual. Thus the conclusion of Jones and Litsenberger was that the market has inefficiencies and hence not as perfect as postulated by EMH.

A number of other studies have appeared in this debate over market efficiency (all of them using earnings reports as the information factor). Those by Beaver,¹⁰ Brown and Kennelly,¹¹ Firth,¹² Jordan¹³ and Kisor and Messner¹⁴ are a few of the studies which provide evidence on either of the sides (i.e. in favour of Ball and Brown or Jones and Litsenberger). Most of the studies used the method of residual analysis. A term which was defined in the course of the development of the work is the "Abnormal Performance Index" (API) which is similar to the cumulative average of residuals U_m used in the study by FFJR. API measures "the proportionate movement in the price of the securities in the sample over some period as a percentage of the proportionate movement expected from securities"¹⁵ as given by the market relationship.

The work by Michael Firth tested a slightly different proposition. This study aimed at testing the impact of earnings announcements of closely competing firms on the price of a share. The hypothesis of Firth was "that use of competing firms accounting and financial results is a significant determinant of a security's price. Thus the announcements of

accounting and financial results are very useful because they not only give information on the firm itself but they also give some indication of how well similar type companies are faring".¹⁶ Firth used the residual analysis and Abnormal Performance Index methods.

The conclusions of Firth were that the information about earnings of a company are used to re-evaluate the price of stocks of closely related companies and the adjustment is in the expected direction, and was about 50 to 80 per cent of the relative price change experienced by the stock of the announcing company. Firth also showed that the adjustment was completed speedily and therefore using such information to increase expected profits is not possible.

Brown and Kennelly¹⁷ in their 1972 study extended the work done by Ball and Brown. Their 'experimental design' was similar to the one developed by Ball and Brown, but they used both quarterly and annual earnings information in their test. The model was such that it allowed a comparison between alternative forecasting rules (naive and regression) and it was also effective in showing the effects of disaggregation of annual EPS into its quarterly components. Their work also used APIs.

It was found that, as far as predictive power is concerned, models based on quarterly earnings were better than those on annual earnings. Also naive models were no worse off than regression models. Ball and Brown's conclusion that most

of the information contained in annual EPS announcement is incorporated well in advance in stock prices was confirmed. They also conclude that the market had only limited ability in anticipating the information contained in quarterly earnings reports "except possibly during the announcement month itself",¹⁸ (They use monthly data.) and therefore predictive models based on quarterly earnings are useful and better (by 30 to 40 per cent over annual EPS models).

One of the latest studies in this area was by Stewart L. Brown in 1978.¹⁹ Brown's contention is that Ball and Brown used monthly data to investigate and came to the conclusion that the market was efficient for monthly trading periods, but still the question is left as to what happens when shorter periods are considered. Brown used daily data and the 'standard residual paradigm' to examine the market adjustment to EPS information. A naive annual forecast model and a sophisticated quarterly forecast model were used to select the securities with unusual earnings reports. The findings which are interesting are: (i) the adjustment process after the announcement of the earnings is lengthy rather than instantaneous (about 45 market days) and (ii) it is possible to earn excess profits (which are substantially more than transactions costs) by purchasing the securities at the time of the publication of the information.

Thus the debate on market efficiency and market adjustment to EPS is rather undecided, though throwing doubt on the validity of the EMH.

Other studies using the market model (or the residual analysis method) to study the adjustment of prices to new information include those examining the impact of announcement of changes in discount rates, etc., on share prices and those studying the impact of buying and selling large blocks of shares.

R.N. Waud²⁰ studied the adjustment of share prices to changes in discount rates, by analysing the random component left in the data after removal of systematic effect (such as market effect) concluded that there is an 'announcement effect' on the expectations associated with discount rate changes and that there is a consensus in the market about what will be the effect on the future of the economy due to such changes. He also pointed out that the market could anticipate decreases in discount rates a few days in advance of the announcement.

On the issue of large block trading and market adjustment a series of articles appeared in the 70s. The evidence presented on this issue cannot be strictly classified as belonging to semi-strong form or weak form of market efficiency and so is discussed here.

Large block trading is usually done by institutional investors and these above studies attempt to see whether this type of trading contributes to or detracts from efficiencies in the market. The studies in this area are generally associated with the names of Scholes,²¹ Kraus and Stoll,²² Grier

and Albin,²³ Reback,²⁴ Dann, Mayers and Raab,²⁵ and Friend and Blume.²⁶ Many of the studies use the 'market model'.

The study by Kraus and Stoll examined whether the price effects "accompanying block trades can be ascribed to a change in the underlying value of the stock (information effect) or to a temporary deviation of prices (distribution effect)".²⁷ It was found that within a day the price reversed from the 'large block trade' price and this price recovery was interpreted to mean that the price deviation was temporary. It should be noted that this price recovery effect was found only for block trades which occurred at a price lower than the market price (and a bulk of the block trades were at a lower price). For those block trades taking place at a price higher than the market (the price prior to the large block trade was taken to be the market price) the subsequent price effects reflected changes in the underlying value of the stock (these were mostly associated with mergers and takeovers). The implications of the study for market efficiency were that, the market was efficient in so far as price recovered rapidly from the large block trade price which was lower than market, and secondly the market is inefficient as large block trades affect market prices at least temporarily (although the block trade does not indicate any new information regarding the value of the stock).

Grier and Albin²⁸ formulated a trading rule based on share price changes surrounding 'significant market events'

like sale of a large block of shares. They hypothesized that patterns can be found in prices following these events, by watching the prices before and at the time of the block trade. The trading rule yielded substantial returns over and above a buy and hold which is indicative of non-randomness (a conclusion clearly contradicting the weak form of EMH and random walk theory).

Dann, Mayers and Raab²⁹ in their study re-tested the trading rule by Grier and Albin, and also tested the speed of price adjustment to new information like large block transactions (in so far as large block trade can be taken as an information event). The study led to three important conclusions: (i) Price dependencies shown by Grier and Albin were found to be financially insignificant (after allowing for operating costs and transaction costs) for New York Stock Exchange non-members (evidence in favour of weak form of EMH). (ii) The speed of price adjustment to information about large block trades was found to be quite rapid (15 minutes to adjust) [(i) and (ii) is evidence in favour of semi-strong form]. (iii) For members (especially specialist) it was found that it is possible for them to make substantial profit from the large block trading rule (evidence contrary to strong form of market efficiency).

Friend and Blume in their 1978 study looked at the question of market efficiency with a view to investigate the effect of increasing institutionalization of stock trading and

ownership in the United States on market efficiency. They found that there is no basis for believing that market efficiency has been or will be impaired by institutional trading. They also conclude that market liquidity and transactions costs have not been adversely affected by institutional trading. They felt that the occasional examples one finds of large institutional purchases and sales associated with substantial and lasting changes in the price of a share are probably due to inflow of significant new information. Their important finding is that although institutional trading occasionally has temporary impact on price, the effect is minor and that investors on the other side of the institutional trade would as a whole benefit from the temporary impact on price.

Thus we find a lively debate on the question of adjustment of the market to large block trades and one feels that further work is necessary before a definite conclusion is made.

Dividends announcements, like earnings announcements, convey important new information to the investors in the market. The specific nature of the information contained in dividends announcements is that current dividends indicate to the investors the future earnings of the firm and this information is used by them to evaluate the value of the firm's share. Here we see that the information content of dividends is closely connected with the earnings of the firm. If the actual earnings announcements convey enough information about

the future earnings of the firm, then apparently dividends announcements contain no new information of value to the investor. But if the EPS announcements do not give an adequate picture of the firm's future prospects, then dividends announcements are important and the adjustment of stock prices to such information, and the 'anticipation' effect of such information on stock prices, are aspects which are relevant for the semi-strong form of the EMH.

A number of studies have been made on the above aspects. The study by Petit³⁰ in 1972 used the residual analysis technique and APIs on data of NYSE for the years 1964-68 to investigate the adjustment of stock prices to dividend information. Dividends announcements were divided into seven categories, from negative dividend changes to positive dividend changes of more than 25 per cent increase. To hold constant the effect of actual earnings reports, the data was classified into two categories, one in which actual earnings exceeded expected earnings and one in which actual earnings were less than expected. The two main conclusions of the paper were: (i) Within earnings categories, the APIs declined along with the decline in the actual dividends reported (i.e. positive, no change or negative). This meant that the market reacts to changes in dividends in a significant way. (ii) It was found that the market also anticipated to some extent the information contained in dividend announcements and that the price adjustment was complete in the same

month in which the dividend announcement was made. When daily data were examined it was found that within a day of the announcement the adjustment is complete.

In contrast to the conclusions of the above study, the work by Watts³¹ came to the conclusion that there is 'little potential information in dividends'. Watts studied the importance of dividends in two ways. First, he studied the relation between future earnings and present and past dividends; second, the relation between unexpected dividend changes (i.e. when actual dividend changes differ from the expected) and stock prices. The conclusion that 'dividend' contains no potential information was partly based on the finding that the investor could not profit by an advance knowledge of the contents of the dividend announcement, because the returns did not even cover the transactions cost.

Michael Laub³² criticised the conclusions arrived at by Watts on the ground that Watts used an annual model on the basis that the annual earnings report of a company are used to declare the dividend while a quarterly model would have been more appropriate. It is because he found that in as many as one-third of the cases examined, quarterly earnings reports were also being used to declare the dividend. Laub's empirical investigation led him to conclude that dividends contain new information which is significant.

Pettit³³ attempted to reconcile the work done by Watts and his own. He restructured the methodologies of the two

papers (Watts and Pettit) to show that the two results are consistent, i.e. dividends contain significant new information to which the market reacts by bringing about adjustment in stock prices. However Watts³⁴ observes that although the reformulation seems to give results in favour of Pettit's conclusions, there are defects in Pettit's method and irregularities in his empirical results, which make any conclusion saying that dividends contain information (on the basis of the above) suspect.

Thus we see that the work on stock price adjustment to dividend announcements has been dominated by the discussion on whether dividends really contain new and significant information or not. Unless they contain new information, any discussion about stock price adjustment to dividend announcements would be unwarranted, because any price adjustment that may be observed during such announcements may be due to factors other than dividend announcements.

Strong Form Tests

The strong form tests of the EMH are concerned with whether all available information is fully reflected in prices in the sense that no individual has higher expected trading profits than others by virtue of his having monopolistic access to some information.

This form of the theory of efficient markets does not appear to be true in reality, because we had already seen some evidence that some people connected with the stock market can

indeed make profits vis. the specialists and the floor traders.

Neiderhoffer and Osborne³⁵ in their 1966 article had pointed out that people who watch the market closely i.e. who take note of the movement of ticker prices can make profits because of non-randomness in ticker price changes. They say that the specialist can make a profit by trading with his own stock of shares at prices just below or above large barriers. For example, they argue, that if the price is rising and there is a large set of limit orders to sell say at 40 rupees, then the specialist can sell his stock at a price of $39-7/8$ knowing fully well that the chances of a price reversal are high due to the barrier at 40. When, because of the barrier, the price declines the specialist can buy back shares at a lower price making a profit.

It was also pointed out in the last sub-section, that Dann, Mayers and Raab have shown that specialists can make extraordinary profits during large block trading and that members of the stock exchange can similarly profit (over and above the normal) during large block trading.

Thus the fact that strong form of EMH is not true in reality is an immediate one. Now we may turn to the question of which groups of investors can make excess profits in the stock market. The extant literature deals only with two types of investor groups, viz., corporate insiders, and mutual funds.

First we shall look at the studies on mutual fund performance.

Mutual funds³⁶ are of two types open end and closed end. Both type of funds are managed by professional managers who analyse and gather a vast amount of information and who are by their profession and contacts bound to have some information in advance. The studies on this aspect are concerned with the question whether open-end mutual funds make profits in excess of the average level, given that they spend a good bit of money on financial research and are managed by professionals.

The early studies in this area are by Treynor,³⁷ Sharpe³⁸ and Friend et al.³⁹

Friend and others, in their 1962 study examined the performance of nearly 189 mutual funds using a composite performance measure, P_1 of the following type:

$$P_1 = \frac{NA_{t+1} + DI + DG}{NA_t}$$

where NA_{t+1} = Net assets per share at the close of a period i.e. net assets held by the fund at the close of period divided by number of shares sold.

NA_t = Net assets per share at beginning of period.

DI = Dividends per share from investment income during period.

DC = Distribution per share from profits realized on sale of securities held by the fund during period.

Although the performances of different types of mutual funds were examined in the study we shall report here only the findings concerning common-stock funds. The performance of

different funds was compared to the performance of the Standard and Poor 500 stock index. Commenting on this above criterion they say that comparisons of this type are really comparisons between results obtained from an unmanaged group of common stocks held for an entire period and those obtained by the management of a mutual fund as it varied the portfolio during the same period.

Their main finding was that over the period examined (i.e. 1953 to 1958), although common stock funds did better than any other types of funds, still their performance was lower than that achieved by the market index. They further found that only 25 per cent of the common stock funds did better than the market index (i.e. Standard and Poor 500 index).

Sharpe's approach was to consider both risk and return as relevant in comparing the performance of different open end mutual funds. It was first assumed that every investor can borrow or lend at some riskless rate of return. If E_i is the expected rate of return on the i^{th} portfolio and σ_i the predicted variability, then an efficient portfolio will be on the straight line.

$$E_i = p + b \sigma_i$$

where p is the riskless rate of return and 'b' the risk premium which is positive for risk averse investors. This line shows the expected rate of return on the i^{th} portfolio for every level of risk (risk being measured by σ_i). An

investor by allocating his funds between buying shares (the portfolio) and borrowing or lending can attain any point of the line

$$E = p + \left(\frac{E_1 - p}{\sigma_1} \right) \sigma$$

"Any portfolio will thus give rise to a complete (linear) boundary of E, σ combinations." And the best portfolio is the one with the highest $E_1 - p / \sigma_1$. This measure Sharpe says can be substituted with ex-post values to give a method of comparing the performance of different mutual funds, i.e.

$$A = p + \left[\frac{A_1 - p}{V_1} \right] V$$

where A_1 is the average annual return on the i^{th} portfolio and V_1 is the standard deviation of the average annual return of the i^{th} portfolio.

The logic of the argument is that if A_1 and V_1 indicate a point on the risk and return diagram, any point on the straight line joining 'p' on the axis and the point is attainable by allocating between portfolio and borrowing and lending appropriately. For example if $p = 3$ per cent, and Y shows the ex-post values A_1 and V_1 for an open mutual fund, then any point on the line XY can be attained by appropriate allocation (Figure 5). Thus one can compare the performance of any other mutual fund (say Z) with Y and one say which is better or worse. In this case Z is worse off because for the same level of return, risk-bearing by Z is higher. Sharpe also calculated the reward-to-variability ratio to compare different

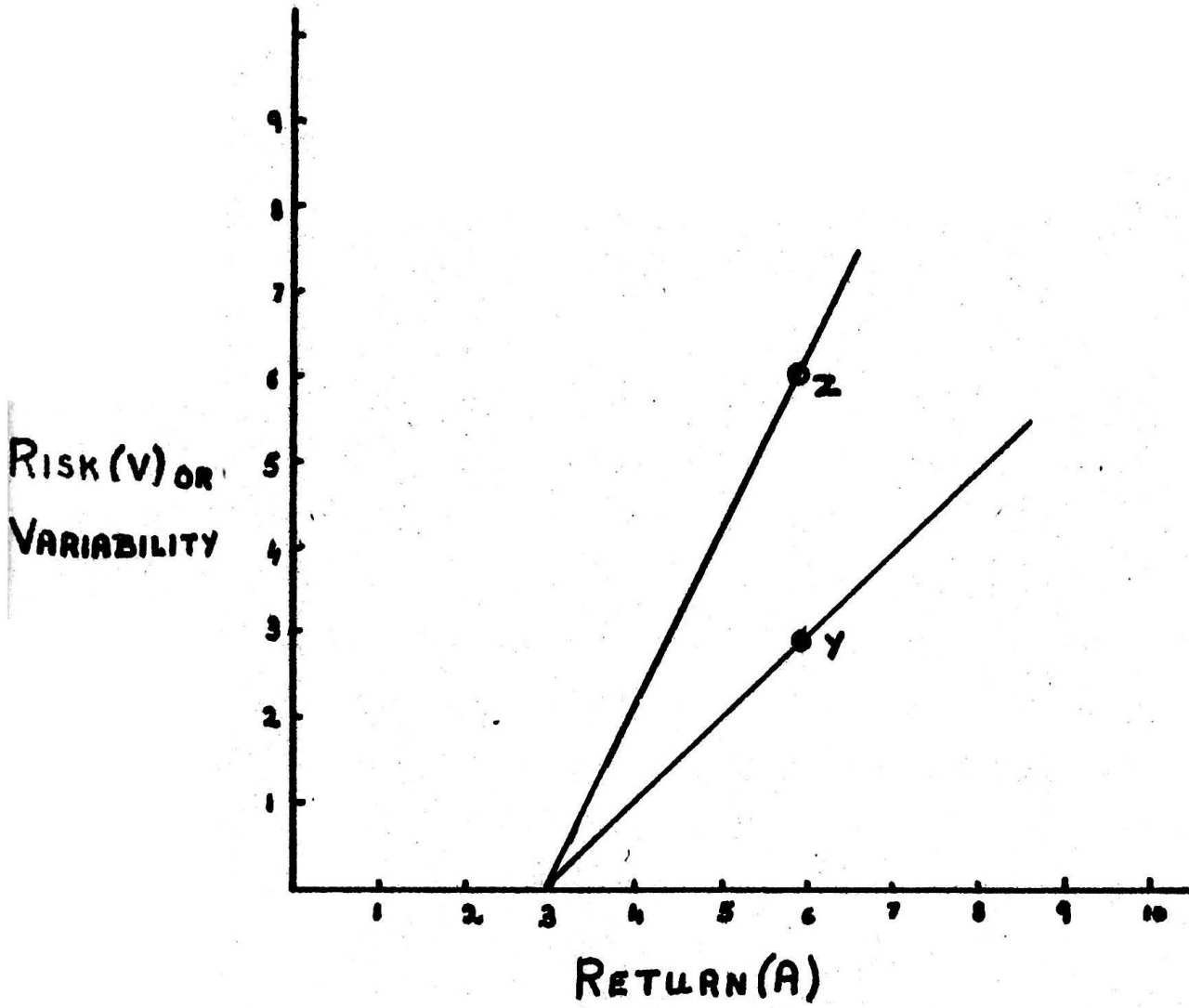


FIG. 5.

mutual funds [R/V ratio = (average return - 3.0 per cent)/variability].

Sharpe compared the performance of 34 mutual funds using this above method. He found differences in performance and also found that these differences are not transitory in nature.

Michael Jensen's⁴⁰ work on open-end mutual funds which was published in 1968 and 1969, is a very comprehensive work on open-end mutual funds. His work improved upon the work done by Sharpe. While Sharpe just compared different mutual funds, Jensen developed a 'norm' against which to evaluate the performance of different mutual funds. If a test of strong form of the EMH is to be conducted, then the norm has to be one which represents the results of an investment policy based on the assumption that prices fully reflect all available information. If, when evaluated against such a 'norm', a mutual fund is found to be better, then one can say the fund has access to special information and also one can say whether one mutual fund is better than the other in uncovering special information.

Jensen also used the risk-return framework but his model was slightly different from the one developed by Sharpe. The 'norm' that was used by Jensen was a market portfolio selected by a naive random selection procedure. The measure of performance was obtained in the following way. If R_{jt} is the return for a mutual fund and R_{Mt} the one-period return on

the market portfolio and R_{ft} the one-period risk free interest rate (all in period t) and β_j represents a measure of risk which is equal to $\frac{\text{Cov}(\tilde{R}_j, \tilde{R}_m)}{\text{Var}(\tilde{R}_m)}$ and α_j is any constant and u_{jt} the error term then we can define the following equation:

$$\tilde{R}_{jt} - R_{ft} = \alpha_j + \beta_j[\tilde{R}_{mt} - R_{ft}] + \tilde{u}_{jt}$$

where tildes indicate random variables and $E(u_{jt}) = 0$ and is serially independent.

In the above equation the intercept α_j is a measure of the forecasting ability of the portfolio manager. If it is positive then he is doing better than a naive buy and hold and we should infer that he has special information and has acted on the basis of it. If α_j is negative, the fund manager is doing worse than a random procedure.

Besides the above method of using intercepts to evaluate the mutual fund performance, Jensen also used a performance evaluation graph similar to the one used by Sharpe. Using the procedure of allocating funds between the portfolio, and lending and borrowing, he generated a market line corresponding to the market portfolio [i.e. the line joining the riskless rate of interest on the y-axis and the risk return point of the market portfolio (using ex-post values of risk and return)]. Using the market line as a 'norm' the relative performance of mutual funds was evaluated.

Jensen investigated the performance of 115 mutual funds over the period 1955-64 with the above framework. The

Standard and Poor index was used as a proxy for the market portfolio. Besides investigating the general question of uncovering of special information by portfolio managers, Jensen also investigated whether the funds are able to get enough returns to justify the charges levied on their investors. Jensen finds that in the case of 89 of the 115 cases examined, the mutual funds did worse than the market portfolio and it was found that, on an average, investors in mutual funds got 15 per cent less than what they would have got by buying portfolios on the market line. Even when loading charges were ignored, 72 of the 115 funds were worse than the 'norm'. A somewhat stronger test conducted by Jensen (to determine whether the funds did better than the 'norm' when all the expenses are ignored) yielded a negative answer. Thus Jensen finds that mutual fund managers have no access to special information, not already reflected in the share prices. Thus Jensen's results give support to the strong form of the EMH, which is a rather surprising result, given that the managers of the funds are professionals with vast funds for market research.⁴¹

The next part of our study on the strong form of EMH concerns the question of whether corporate insiders viz. corporate officers, directors, and large shareholders can make excessive profits through their access to inside information. This part of the study has also another aspect which concerns whether information about insider trading is profitable

for the normal investor or not.

A number of studies made on the question of profit-making by insiders are not available for study as they have not been published. However, from the information given about these studies, one finds that most of the ones which conclude that insiders cannot make a profit have not been published while the few that provide evidence in favour of profitable insider trading have been published. A summary of the published work would thus give a biased picture.

Here we shall summarize the findings of these studies, as mentioned by Jeffrey Jaffe⁴² in his 1974 study.

Some researchers e.g. Rogoff,⁴³ Glass,⁴⁴ Lorie and Neiderhoffer⁴⁵ while examining the profitability of insider trading have found on investigating months of intensive insider activity (these are months when the number of sellers exceed the buyers or the number of buyers exceed sellers by a certain number only as far as insiders are concerned) that insiders can predict the movement of stock price (of their own company) upto six months in future. For example to quote Lorie and Neiderhoffer: "This study indicates that proper and prompt analysis of data on insider trading can be profitable, although almost all previously published studies have reached the contrary conclusion. When insiders accumulate stock intensively, the stock can be expected to outperform the market during the next six months. Insiders tend to buy more often than usual before large price increases and to

sell more than usual before price decreases."⁴⁶

On the other hand Wu⁴⁷ and Discroll⁴⁸ find no evidence of successful forecasting by corporate insiders. Discroll examined data on insider trading before dividend changes and Wu studied the price movements in the month which comes after a month of intensive insider trading. Scholes⁴⁹ in his 1972 study used residual analysis to examine secondary offerings which are generally issued by insiders. He found that the residuals drop by 1 per cent on the day of the offerings and that there are no systematic changes after that. Besides, Scholes also found that complete adjustment to information contained in a secondary offering (a secondary offering is a signal for re-evaluation of a firm's stock by investors) was completed within six days and as the rules in NYSE are that the insider should reveal his identity within six days of the offering, this means that the market has adjusted to the information before official reporting of the identity. This piece of evidence is clearly in favour of the semi-strong form of EMH.

Jeffery Jaffe in his 1974 study using residual analysis, finds that insiders do possess special information. But he finds that after adjustment for transactions costs only the intensive trading samples (of the three samples used in the study: Initial Sample of all insider transactions, Sample of large transactions, Intensive trading samples) give significant profits (when the holding period is 8 months). Jaffe

also finds that the information contained in the official publication on insider trading is not discounted by the date of the publication, and that it is possible to make profits using the information contained in the publication as the adjustment is gradual. These findings are contrary to both the strong form and semi-strong form of EMH.

The last study which we shall now briefly touch upon concerns dissemination of second-hand information. Davies and Cane⁵⁰ find that stock analysts' recommendations are published in the Wall Street Journal a few days after these recommendations were first given to the analysts' own clients. They find that this secondary dissemination does affect stock prices and that the effect is not reversed within the 20 days subsequent to the secondary dissemination. This means that the recommendations do have some economic content and therefore are economically valuable for the analysts' clients. They infer from their investigation that purchase or sell recommendations released to a small group of investors are not immediately and fully reflected in the stock price. They conclude that the fact that full stock price-adjustment does not take place on primary dissemination goes against the claims of the strong form of the efficient market hypothesis.

Thus our study of literature on the strong form of EMH clearly shows that there are a number of groups of investors who have inside information and who can profit

by this inside information. The studies also show that there is a delay in adjustment of prices to some publicly available information (e.g. information on insider trading). The last study mentioned in this sub-section is interesting because it reveals that when information is available only to a few people, their actions would not result in a complete market adjustment and therefore the information is valuable even after it is made public; a fact which clearly points to the kind of process of adjustment by the market to information and the kind of behaviour the prices follow as new information surfaces.

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