I. INTRODUCTION

Many papers have been published in the Journals about the use of computers for actuarial work. Generally these papers deal with data processing operations such as valuations, rate calculations, pension fund administration, etc. Two Institute papers have, however, dealt with the use of the computer for valuing equities and for assessing gilt-edged situations (see G. T. Pepper, J.I.A. 90 and D. Weaver and M. G. Hall, J.I.A. 93). Apart from these two valuable contributions there has so far been little reference in the Journals to the use of the computer for investment analysis.

The Society of Investment Analysts has displayed great interest in this subject; in fact, for each of the last three international conferences of the Investment Analysts a report has been prepared surveying a large number of computer projects operated by stockbrokers, bankers and investment institutions in U.S.A., U.K. and Europe. A study of the successive reports, summarised in Part I below, affords evidence as to the success or otherwise of the various types of scheme. Originally U.S. banks and stockbrokers took up the computer with great enthusiasm. Vast amounts of data were assembled and recorded on tapes. Many ambitious and expensive projects were organised with varying degrees of success. Some projects in fact foundered under a sea of paper, producing a vast output of indigestible statistics. More success was achieved with specialised applications, mechanising the extensive calculations that are regularly required in comparing certain types of shares (U.S. utilities, life assurance shares, fire and casualty shares, etc.). We believe that the most useful and profitable computer application to investment analysis lies in the study of certain specific groups of shares and stocks, for which a considerable volume of statistics are readily available and need to be analysed. Examples of these groups applicable to the U.K. markets are:
The Computer for Investment Research

Investment Trusts
Convertibles
TV rental shares
Gold mining shares
Mining finance shares

Detailed studies carried out by the writers into investment trusts and TV rental shares are described in Part II and Part III of this paper.

PART I

DEVELOPMENT OF COMPUTER PROJECTS

2.1. The Analysts Society Reports

These three reports were based on data submitted to the editors (Messrs. J. F. M. Peters and J. Plymen) by a variety of financial and professional organisations. Some organisations known to be engaged on major computer studies refused to contribute to these surveys, fearing that they would be revealing information to their competitors. In consequence the material that was made available could well have been a bad sample of the computer investment activities at the time. Despite this difficulty in collecting the data, the scope of the activities that were released for publication and their success or otherwise makes an interesting study. Broadly, the various computer projects can be classified under the following headings:

I Pricing of specific equity shares.
II Data processing of investment statistics.
III Selecting the best share portfolios.
IV Analysing specific classes of share where detailed statistics are regularly available.
V Facilitating the work of the analyst using industrial models to forecast earnings, etc.
VI Technical analysis.
VII Fundamental research, usually undertaken by University economists.

2.2 The 1966 Report

The feature of the 1966 report was the high proportion (seven out of thirteen) of the applications concerned with the processing of investment statistics. Processing took the form of recording on magnetic tape a vast amount of price and accounting data and then
analysing this material to produce masses of figures, designed perhaps to facilitate comparison of a particular share with others in the same industry or with the whole market. These comparisons, often made by reference to almost every possible investment statistic, produced a most elaborate array of figures, usually overwhelming the analyst with indigestible data. Of the remaining applications, three described ambitious statistical studies using regression analysis to "price" individual shares. Finally there were three projects, using elaborate mathematical techniques, designed to select the "ideal portfolio" most suited to the clients' requirements.

2.3 The 1968 Report

Two years later the 1968 report revealed a considerable extension of computer activity, particularly in the U.S.A. Presumably the high level of the Stock Exchange turnover, combined with the activities of the "go-go" mutual fund managers, continually looking out for situations, served to encourage the development of new computer projects. No less than eight such projects designed to select specific shares for purchase or sale were then described. Most of these were designed by U.S. stockbrokers or bankers, their projects usually covering large numbers of companies, making use of extensive input material, and requiring a large force of analysts.

Data processing applications were represented by eight projects designed to facilitate the routine work of the analyst. Some of the original schemes which had produced such a mass of figures and used so much paper had been refined so as to confine the print-out to the more essential items.

Portfolio selection was still receiving some attention, although the elaborate I.B.M. programme, making use of the Markovitz principle (maximising returns allowing for the degree of risk) appeared to have received little practical support. This Markovitz principle, although most elegant in theory, imposes impossible demands on the analyst, needing inputs of future earnings allowing for risk and market factors that cannot be quantified. A more practical experiment in portfolio selection is that developed by Lionel D. Edie, Investment and Economic Counsellors. This scheme, described in detail in the contribution "Use of Computers for Investment Purposes" by J. Plymen to the 18th International Congress of Actuaries, uses linear programming to improve the quality of the portfolio, allowing for certain constraints regarding the number of holdings. There is little doubt that this system, if it could be provided with sufficiently reliable estimates of next year's earnings, etc., offers considerable prospects.
Apart from these rather ambitious schemes, some progress was being made by 1968 with the use of the computer to facilitate analysis of specific classes of share such as U.S. insurance shares, U.S. utilities, airlines, etc., where there is a considerable volume of regular trade statistics, requiring extensive analytical calculations. In addition, several firms were developing techniques for facilitating analysts’ forecasts using econometric models of an industry or a company. These models, fed with alternative assumptions as to turnover, margins, cash flow, etc., enable the analyst to try out a variety of assumptions making sure that his estimates of likely earnings and capital needs are consistent. Some reference was also made to computerising technical analysis (i.e., the study of patterns of share price movements and of the volume of dealing). Such activity can really be carried on only in the U.S.A., where adequate statistics are available regarding markings. Probably this technical analysis, combined with fundamental and economic studies, has some possibilities. However, little published information is available, particularly regarding the more successful operations!

With the availability, particularly in the U.S.A., of extensive taped statistics of prices, earnings, etc., for many shares for a long period of years, much activity was developing among university-based economists and mathematicians attempting to test the validity of various investment laws and hypotheses.

2.4. The 1970 Situation

For the 1970 report the editors wrote to all the organisations that had provided evidence of computer activity in 1968, asking what progress had been made and how the system, if still operating, had been developed. Several of the earlier contributors failed to reply and in these cases the editors assumed that the original projects had been abandoned. Undoubtedly the slump in the Wall Street market had necessitated considerable cutting back of expensive analytical and computing activities. In fact, one firm of Wall Street stockbrokers who contributed to the 1968 report had since gone into liquidation, whilst another firm responsible for a most elaborate computer study subsequently encountered very serious financial difficulties and was saved from a similar fate only by a massive injection of external capital.

The main casualties among the computer projects came among the Category I group, those elaborate statistical schemes for pricing individual equities. Some of these schemes seem to have been abandoned or converted from their original objective to a rather less
ambitious scheme designed to screen a large number of shares with
the intention of picking out interesting situations for the analyst to
exploit by traditional methods.

For Category II, however, the data processing of investment
statistics for the convenience of the analyst, several of the 1968
projects had been intensively developed, and were proving highly
successful. In particular, the schemes of White Weld in the U.S.A.
and Hoare & Co. in the U.K. now provide a most comprehensive
computer statistical service supplying clients with a wide range of
valuable investment data as well as making available all necessary
statistics to clients' analysts using a time-sharing computer. These
two projects undoubtedly provide a most valuable service to the
investment community.

2.5. 1971 Developments

As regards the other applications, the trends that were evident in
1968 appear to be still operating. Much effort is being devoted to
analysing by computer those specific investment categories where
considerable regular statistics are available and extensive calculations
are required (Category IV). In classes such as utilities and life
assurance shares the U.S. analyst has a large number of companies
to cover and the detailed calculations of earnings, etc., are enormously
facilitated by the computer. In the U.K. the number of specific
classes, where companies are sufficiently similar for detailed com-
parison, is rather more limited. For example, there is little point in
devising elaborate schemes for assessing, say, clearing bank shares
when the U.K. market has only six companies to be covered. In the
U.K., however, there is one unique situation, that of the investment
trusts. This category of closed end investment trusts scarcely exists
in other markets. Conversely, in the U.K. there are something like
120 investment trust shares, requiring continual calculations of asset
values. The methods used by the writers to analyse U.K. investment
trusts are described in detail in Part II below. Work on technical
analysis continues in the U.S.A. whilst certain universities in the
U.S.A. and the U.K. are using the growing volume of investment
statistics for their research purposes.

The technique of using a computer to improve and refine the
analyst's estimates of earnings and capital needs (Category V) offers
considerable scope for further development. These essential esti-
mates will clearly be much improved if they are based on computerised
industrial models. With these models various assumptions as to the
rate of turnover and changes in profit margins can be associated with
the appropriate cash flow and capital requirements. An example of this technique applied to U.K. TV rental shares is set out in Part III.

PART II

ANALYSIS OF INVESTMENT TRUSTS

3.1. Closed End Trusts

The "traditional" closed end investment trust is financed by debenture, preference and equity capital and is formed for the purpose of managing an investment portfolio. These provide the private investor with the benefit of professional management and allow him to participate in a wide range of investments in U.K. and overseas, many of which would normally be beyond the means of the small shareholder. The fixed interest capital provides gearing so that the shareholder benefits particularly from favourable markets.

3.2. The Asset Value

As the normal investment trust has no trading activities, the value of the equity capital is readily assessed as the market value of the underlying securities, reduced by the cost of paying off the prior charge capital. This figure, calculated on a per share basis, is known as the "asset value". The share price is obviously always of the same order as the asset value, the difference depending on the merit of the trust in the eyes of investors. For a trust with an exceptionally good record of past investment success, investors may be so keen to participate in future results that they will pay more than the asset value per share. In most cases, however, the share price is below the asset value, reflecting perhaps the administrative costs which reduce the total shareholders' income below that obtainable from a direct holding in the whole underlying portfolio. For trusts with a particularly poor past record or perhaps with an investment distribution that is currently unfashionable, the discount can be relatively high, up to say 20%.

Investors considering a trust share need to know the current discount of the price on the asset value so as to compare this figure with other known features (the past record, the gearing, the percentage of investments in U.S.A., Australia, etc., the yield on the underlying equities, etc.). Until recently, before the advent of the computer,
The asset value was published by the Trust Managers only once a year with the annual report. Between these year-end figures asset values had to be calculated laboriously by applying index movement factors to previous year-end valuations. For many years the only indication of the asset value consisted of tables published by the leading jobbers on a monthly basis.

3.3 Daily Discount

In recent years, however, the position from the point of view of the analyst has much improved. Most of the trusts, no doubt making use of their own computer facilities, now publish asset values at quarterly or monthly intervals. With these frequent official valuations there is now little difficulty in estimating the asset value every day using the latest official figures, adjusted subsequently by the movement of the relative share price indexes. In fact, now the leading jobbers and the half-dozen or so specialist stockbrokers in this field all have a daily computer run designed to update the official valuations by the latest index figures. Clearly this computer facility greatly assists the trust share analyst.

With the discount readily available each day for all the 100 or so important trusts the way is clear for some statistical study to determine those shares that are cheap or dear at any given time.

3.4. Computing the Discounts

The average discount for all the trusts changes from day to day according to market conditions. Around this average overall discount the figures of the individual trusts are arranged, ranked in some way or other according to their merits or demerits. Preliminary tests, by plotting scatter diagrams, suggested that the more important features likely to affect the trust's rating were:

(i) Relative investment performance over the last five years.
(ii) Proportion of U.S. investments.
(iii) Yield on the underlying portfolio.
(iv) The gearing.

Item (i) was taken as the "management rating" published in the Investors Chronicle survey 31.10.69. For the 93 trusts included in that survey a regression analysis was carried out using the Baric multiple linear regression analysis programme. Results are given below:
A multiple correlation coefficient of 0.76 was obtained when using all the above variables, but some of the variables were found to make an insignificant contribution. The best set of variables produced the following solution:

\[ Y = 27 - 1.56X_1 - 0.22X_2 - 0.38X_3 \]

where:

\[ Y = \text{discount \%} \]

\[ X_1 = \text{5-year management rating} \]

\[ X_2 = \text{dollar \%} \]

\[ X_3 = \text{gearing \%}. \]
The multiple correlation coefficient was 0·69 and all the variables were significant at the 0·1% level.

3.5. Predicting Price Changes

However, before using more analytical and computer time, it was felt desirable to check whether the difference between the actual discount at any given time and the computed discount had any predictive value in terms of future price performance. Unfortunately, extensive tests showed that there was only a negligible correlation between the difference of actual and expected discount and the price changes over the next six months, i.e., that a share apparently cheap by reference to the computer showed practically no sign of rectifying this anomaly by a subsequent above average price performance.

This failure of the regression analysis to select cheap or dear shares was somewhat of a set-back. Perhaps the reason is that the regression technique is "too clever for the market". If this is the case a straightforward technique more geared to market movement and less linked to elaborate mathematical techniques might perhaps be more successful. There seemed little point in the circumstances in pursuing further the regression analysis. As an alternative, tests were made by drawing charts for 33 trusts, showing the level of the discount over a period of three years and plotting the trend line by hand to measure the dispersion of each observation from the "norm" (see Fig. 1). In each case the dispersion was measured and the angle of the trend line (i.e., whether the mean discount was increasing
or decreasing) determined. Another regression analysis was made comparing the dispersion and the slope of the trend line, as independent variables, with the subsequent movement over the next six months of the discount. This study revealed a multiple correlation coefficient of .73, suggesting that the statistical techniques built around the movement of the discount could be expected to predict future share price changes and perhaps indicate whether the shares are cheap or dear.

3.6. Time Series Analysis

Examination of the time series represented by the discount data shows that the series are characterised by variations of the discount about its average which seem to be of a random nature but with a fairly stable distribution and rather short time span (see Fig. 2). Furthermore, the trends (i.e., direction of movement of the average discount) seem to persist for a fairly long time relative to the intervals between the larger fluctuations of discount. Under such conditions the size of the deviation of the discount from its average could well be negatively correlated with changes in the discount between the present time and some time in the future. The length of this time span should not be so short that the discount has not had time to return, so to speak, from its excursion away from the average, nor so long as to be seriously affected by any trend which might be present.
3.7. Control Charts

A form of control chart technique, familiar to inspection departments in industry, suggests itself as a possible means of identifying the major turning points.

In the industrial context a machine may be making a certain part which has a specified diameter. From time to time a part is taken from production and its diameter measured. This measurement is recorded on a graph. The diameter of the part will not remain precisely the same from one part to the next, even assuming the process to be under proper control, but will fluctuate in a random manner. The degree of fluctuation will depend on various factors such as the capabilities of the machine and its operator. If the deviations from the normal diameter are noted, their standard deviations can be calculated. The control limits can then be drawn on the graph at, say, three standard deviations, as shown in Figure 3 below. The probability of a deviation lying outside the three standard deviations limit is about three in a thousand, so for practical purposes one can assume that if such a deviation did occur the process was temporarily out of control, and the machine should be stopped. Practical quality control schemes are usually rather more sophisticated, but the above example serves to explain the general principle.

The application of this principle to investment trust share discounts involves the calculation of the standard deviation of the fluctuations of the discount about its average value and then setting the control limits at a suitable multiple of standard deviations from the average discount. The control limits should be set so that they are exceeded only when a major turning point occurs in the discount. Thus, penetration of the control limits should signal a possible "buy" situation (upper limit) or "sell" situation (lower limit).

3.8. Exponential Smoothing

The first necessity for a practical system is to have a mathematical means of calculating the moving averages of the discounts, rather
than fitting them by eye on graphs. A suitable method is that known as exponential smoothing, which has certain advantages from the point of view of computer operation. The principle is that an average is obtained by applying progressively decreasing weight to the data as one goes back in time. The more frequently encountered method of simple moving averages applies a constant weight to all of the data. It would seem more logical to give more weight to recent data than to earlier data.

An exponentially weighted moving average is calculated by applying to the data weights which decrease in an exponential manner, that is, by a constant proportion which is known as the smoothing factor (usually denoted by the Greek letter, $\alpha$). However, instead of calculating a set of weights, multiplying each term in the series by its weight and then summing these products (which is the usual way of obtaining averages), the same result can be obtained in a far simpler manner. It can be shown (see Appendix I) that the exponentially weighted average is given by the equation:

$$\text{New average} = \alpha \text{ (current data)} + (1 - \alpha) \text{ (previous average)}.$$ 

Thus, to calculate the new average we need know only the value of the last average and the value of the current data.

The smoothing constant can be set at any value between 0 and 1. The problem is to choose a low enough value of $\alpha$ so that the data is sufficiently smoothed to give a meaningful average, but not so low that, if a fairly sharp change in the trend of the data occurs, the average will fail to respond quickly enough. Experiments carried out on discount data suggest that a value of $\alpha$ between 0·10 and 0·25, depending on the time period between successive data values, gives the best results.

3.9. Control Limits

The setting of control limits on the deviation of discount from its average involves the calculation of a standard deviation of the discount deviation. In practice it is simpler to use a different measure of dispersion, known as the Mean Absolute Deviation (MAD). The calculation is very similar to that used to obtain the exponentially smoothed average.

New MAD =

$$\alpha \text{ (absolute value of current deviation)} + (1 - \alpha) \text{ (previous MAD)}.$$ 

This measure of dispersion is discussed in some detail in R. G. Brown’s book *Smoothing, Forecasting and Prediction of Discrete Time*...
Series, where it is shown that if the deviation is normally distributed
about its average, the mean absolute deviation is approximately
equal to 0·8 times the standard deviation.

Experiments carried out to determine the best placing of the control
limits suggest that they should be set at about 1·6 MAD (i.e., 1·3
standard deviations) from the average, when the major turning
points will generally be successfully indicated by penetration of the
control limits.

The points are illustrated in Figure 4 which shows the discount
history of Bishopsgate Trust shares over the past few years, along
with an exponentially weighted average and the two control limits.
The smoothed average seems well centred, following the long term
trend but not responding unduly to short-term fluctuations. It
will be noticed that the control limits are fairly close together in
1967, but widen considerably in subsequent years. This is because
the discount fluctuations were of fairly small amplitude in 1967 and
became much larger later. The control limits are penetrated only
when the discount reaches a major turning point, but in 1967 the

\[ \text{FIGURE 4} \]
major turning points represented much smaller deviations from average than in later years. Such small deviations are not likely to prove very profitable. Hence, the method used to signal investment opportunities should take account of the size of the deviation as well as its relative size. Experiments have shown that it is not advisable to take action on deviations much less than about five percentage points from the average.

3.10. Practical Operation

A practical system has been devised around the theoretical features described earlier, and is being run on an experimental basis. Every week the discounts of 94 trusts are calculated and used as input to a computer programme which calculates new values for the exponentially smoothed average, the trend, and the upper and lower control limits. A smoothing factor of 0.13 is used. The control limits are set a minimum of six discount points from the average, but will be automatically wider apart in the case of a volatile share. If the discount penetrates the control limits, a buy or sell signal is printed. The computer also calculates and prints the value of a buy/sell indicator which gives an indication of the position of the average discount for all the shares in relation to the average upper limit discount and the average lower limit discount for all the shares. This indicator can vary between +100 and −100; the former figure would arise when the majority of trusts were showing “buy” signals, and the latter when “sell” signals were predominating. An example of a page of the weekly print-out is shown in Figure 5 below. This is in fact the last page of the print-out for 19th March 1971.

![Figure 5](image-url)

<table>
<thead>
<tr>
<th>Designation</th>
<th>Disc.</th>
<th>Avg.</th>
<th>Diff.</th>
<th>Trend</th>
<th>Upper</th>
<th>Lower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stockholders</td>
<td>−3.5</td>
<td>−5.9</td>
<td>2.4</td>
<td>0.6</td>
<td>−0.2</td>
<td>−12.2</td>
</tr>
<tr>
<td>Trans Oceanic</td>
<td>6.2</td>
<td>2.8</td>
<td>3.4</td>
<td>7.7</td>
<td>8.3</td>
<td>−3.7</td>
</tr>
<tr>
<td>Trust Union</td>
<td>16.1</td>
<td>14.9</td>
<td>1.2</td>
<td>−5.7</td>
<td>20.8</td>
<td>8.8</td>
</tr>
<tr>
<td>Trustees' Corpn.</td>
<td>15.0</td>
<td>16.4</td>
<td>−1.4</td>
<td>−9.3</td>
<td>22.6</td>
<td>10.6</td>
</tr>
<tr>
<td>U.S. &amp; General</td>
<td>12.7</td>
<td>12.9</td>
<td>−0.2</td>
<td>−9.9</td>
<td>18.9</td>
<td>6.9</td>
</tr>
<tr>
<td>United Brit. Sec.</td>
<td>15.6</td>
<td>14.7</td>
<td>1.0</td>
<td>−6.0</td>
<td>20.5</td>
<td>8.5</td>
</tr>
<tr>
<td>U.S. Deb. Corpn.</td>
<td>15.0</td>
<td>15.4</td>
<td>−0.4</td>
<td>−3.6</td>
<td>21.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Winterbottom Tst.</td>
<td>9.0</td>
<td>9.6</td>
<td>−0.6</td>
<td>4.1</td>
<td>16.2</td>
<td>3.2</td>
</tr>
<tr>
<td>Witan Inv. Tst.</td>
<td>8.7</td>
<td>2.4</td>
<td>6.3</td>
<td>10.7</td>
<td>7.4</td>
<td>−4.0</td>
</tr>
<tr>
<td>Yeoman Inv. Tst.</td>
<td>17.5</td>
<td>16.3</td>
<td>1.2</td>
<td>−7.2</td>
<td>22.1</td>
<td>10.1</td>
</tr>
</tbody>
</table>

BUY/SELL Indicator: 33

The system identifies situations where the discount appears to be unusually low or high for the particular company, but this information
should of course be used in conjunction with a knowledge of the investment trusts because situations may arise where there are good reasons for the occurrence of an exceptional discount.

3.11. Performance Testing

The testing of the performance of any system which recommends the purchase or sale of shares at a particular time presents certain problems. At first sight the objective might seem to be to simulate some type of practical operation, but this entails devising a set of investment rules, some of which may be contentious and could radically affect the performance. In point of fact such a test was applied to this system and the results seemed very encouraging, but it was felt that a less practical but statistically more meaningful test should be devised.

The method chosen for testing the performance of the system was to run the programme twice a month over a two-year period from June 1968 to June 1970, covering 93 trusts, and whenever a _buy_ or _sell_ signal occurred to note the price of the share at the time, and also the value of the F.T. Actuaries Index for investment trusts. The ratio was calculated of each share price at the time of the signal to the price at an arbitrary closing date (24th June 1970). Similarly, the ratio was calculated of the index on each of these occasions to its value at the closing date. The share price ratios were then compared with the index ratios. The procedure was carried out separately for the _buy_ and _sell_ signals; details are given in Appendix II.

The results were rather unexpected in that the average gain of all the _buys_ over the index was just over 1%, whereas the average loss of all the _sells_ compared with the index was nearly 10%. It was felt that an explanation might be found in the fact that the period covered by the test was one in which prices fell rather heavily, and that the results might have been different in a bull market. A subsequent test covering the first nine months of 1971 gave the _buys_ an average gain of 4.1% over the index, and the _sells_ an average loss of 6.8% compared with the index, which perhaps lends some support to the suggested explanation.

3.12. Conclusion

Although the apparent advantage which the system shows over the index is not particularly spectacular, it should be remembered that the test was designed to show whether there was any statistically significant improvement over the index rather than to simulate practical operations. However, the differential performance between
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the BUYS and SELLS suggest that some improvement might be expected if a means of allowing for the overall price trend were to be incorporated.

The performance of the system described above, which is being run on an experimental basis, seems sufficiently promising to encourage further research. The authors are aware that certain statistical aspects of both the control chart system and the regression analysis need closer investigation.

The initial approach using regression techniques, although unsuccessful in predicting price movements, could probably with advantage be explored further. If a regression run were carried out regularly it would be possible to observe the changing weights which investors were putting on such variables as past performance, gearing and so forth. This knowledge should lead to a better understanding of the market and might form the basis of a relative price change predictive model.

PART III

PROFIT FORECASTS FOR TV RENTAL COMPANIES

4.1. TV Rental Arrangements

In the United Kingdom a television set can be bought outright, bought on hire purchase, or rented. Approximately 50% of sets produced are rented through six companies. Rental agreements between the customer and the rental company usually cover a period of one year, rental being paid on a weekly, monthly, quarterly or annual basis; it is usual for a lump sum representing a number of weeks’ rental in advance to be paid by the customer when a contract is made to rent a new set (as opposed to the renewal of an existing contract). One set will continue to generate revenue, on a declining scale, over a period of about ten years.

Under a given set of economic and fiscal conditions forecasts of the size of the television set market for several years ahead can be made, and the proportion of sets rented and share of the market held by any one company can be estimated, thus leading to a forecast of new sets rented out. A knowledge of the age distribution of existing sets, together with the estimate of new sets enables a forecast of earnings to be made; also, given the set price, forecasts of capital expenditure are possible. Similarly, a knowledge of existing operating costs and the forecast of new sets to be rented enables forecasts of operating costs to be made. Further depreciation costs, interest charges and
tax charges can then be estimated, thus leading to forecasts of earnings, cash flow and financing requirements.

There are, in fact, distinct analogies between TV rental business and life assurance. TV sets have a broadly predictable life span, subject to a rate of scrappage, like a human mortality experience. New TV rental business has to be financed by the equivalent of a new business strain, recoverable over the life time of the sets. Rental terms include a fixed loading for future servicing and collecting costs, similar to the expense loading in life assurance contracts.

In practice the operations of this industry can be readily simulated by a computer model, and the facts that the financial forecasts are subject to quite a number of estimates about which there may be various views held, and that the industry is somewhat at the mercy of changes in fiscal policy which can affect market forecasts, prices of sets, capital allowances, advance rental requirements, etc., lends further weight to the use of a computer as an aid to investment analysis in this field.

4.2. The Computer Programme

The computer programme which has been written around previous analytical work is designed to provide a set of financial results for any single rental company, covering a period up to five years ahead. It has been written for use with a computer terminal and is in conversational mode, so that the user may change the values of some of the input variables while the programme is running and select the output information as required. The input data is classified as either fixed or variable; the former being data which the user cannot alter while the programme is running, comprising information taken from previous years' financial results. The variable data can be altered while the programme is running and generally speaking consists of the user's estimates.

When the programme is run the computer starts by printing all the fixed input data, followed by the initial values of the variable input data. All the necessary calculations are performed and the results printed. The user is then given the opportunity to change the values of one or more of the input variables, after which the calculations are repeated. The user can elect to have the complete set of results printed, or he can select individual items. An example of the computer print-out is given in Appendix III.

The programme can also be set to operate in a manner which is appropriate to special studies, such as investigating the effects of different rates of inflation on each of the rental companies. In this
case all the changes which the user requires to make to the values of certain input variables are placed in an instruction file. The computer reads this file, performs the operations required, and delivers the output to a line printer (which prints some 50 times faster than the teleprinter terminal). Using this mode of operation, a series of experiments can be performed in a few minutes which would represent weeks of work for one investment analyst.

4.3. Calculations

The basic calculations are quite general:

Pre-depreciation profits = revenue less operating costs.
Pre-interest profits = pre-depreciation profits less depreciation costs.
Pre-tax profits = pre-interest profits less interest charge.
Net profits = pre-tax profits less tax charge.
Earnings = net profits less minority interests less preference dividends.

In order to carry out these basic calculations values must be assigned to some of the variables on the right-hand side of the equations. The programme arrives at these values by using the input data and by making certain assumptions mentioned below.

Revenue, operating costs and depreciation costs are calculated as outlined earlier. The programme allows various depreciation methods to be used, as well as a mixture of methods. (This situation occurs in the case of one rental company.)

To arrive at the interest charge the programme next carries out cash flow calculations, which are:

Cash inflow = pre-tax profit plus depreciation cost minus tax and dividends payable.
Cash outflow = set expenditure plus or minus working capital change.

The interest charge is then taken to be equal to last year's value plus the change in interest payable; the latter being equal to the net cash flow multiplied by the prevailing rate of interest for loans.

A problem arises in that the interest charge is dependent on the cash flow which is dependent on pre-tax profits which in turn are dependent on the interest charge. The programme solves the problem by a process of iteration: a trial figure is used for the interest charge so as to arrive at a cash flow figure, from which a new interest charge is calculated. This process is repeated until the new interest charge stabilises. Iterative techniques, which would in many cases be extremely tedious if carried out manually, are frequently encountered in computer programmes.
In the cash flow equations the tax payable refers to tax incurred on last year’s operations and payable during the current company year. The dividends payable should consist of last year’s final dividend plus the interim dividend for the current year, but as the latter figure is not known at this stage of the calculations an approximation is made by using last year’s dividends in toto.

For the calculation of cash outflow, an estimate of set expenditure is obtained from the revenue section of the programme (the set price being supplied by the user). An estimate of working capital change is obtained by assuming that the ratio of working capital to revenue remains constant.

The calculations of the tax charge appearing in the profit and loss account and the tax actually payable are done separately, involving transfers to and from the tax equalisation account. Minority interests are calculated by assuming that their ratio to net profits remains constant, the ratio being calculated from last year’s figures; the user can, however, alter the ratio. Preference dividends are assumed to continue at the same value as for last year, but again the user may alter this figure.

The programme makes allowance for the effects of a convertible debenture where the first conversion date falls within the five-year forecast period. A modified earnings per share figure is obtained on the assumption that full conversion takes place in the first year allowed.

The forecast of ordinary dividends is obtained by assuming a constant payout ratio, which is calculated on last year’s results. The user has the facility of changing the payout ratio in any or all of the forecast years.

Allowance can be made for the effects of inflation. Three different inflation effects are concerned:

- Operating cost inflation.
- Set cost inflation.
- Revenue inflation.

The first two are likely to have similar values, nevertheless the programme allows them to be treated separately. Revenue inflation is generally lower than the others because of a reluctance on the part of the rental companies to increase rentals on existing sets.

The programme also takes into account the possible effects of a value added tax. It is assumed that this tax will operate in such a way that some items purchased by a rental company carry tax, and similarly the rental charges received from their customers will also
carry tax. The amount of value added tax payable by the company will be represented by the difference between that received with the revenue and that paid out with the operating costs. Details of the tax have not yet been formulated, but it is possible that there may be several rates of tax depending on the goods or services concerned. The programme caters for two rates, one applicable to costs and one to revenue.

4.4. Conclusion

This model, although embodying simple general principles, is tailored to the specific characteristics of a single industry. Its construction therefore required an intimate knowledge of the industry as well as mathematical and programming ability. It is very unlikely that the necessary skills will be found in one person, and in fact this model was the outcome of close co-operation between several people.

The main advantages which such a model offers are twofold, firstly the ability to up-date financial forecasts promptly, and secondly the ease with which elaborate sensitivity analyses can be carried out (i.e., the sensitivity of results to changes in input.) Such analyses reveal the vulnerability of the industry or of individual companies to changes in the environment. They also assist the analyst in determining how accurate his input forecasts should be, and hence the amount of time he should spend on various aspects of his research.

PART IV

A FINANCIAL MODEL FOR SOUTH AFRICAN GOLD MINES

5.1. The same sort of techniques which were applied to the TV Rental Company computer model can be used for the analysis of South African gold mining shares. The 40 or so mines form a fairly homogeneous group, and a considerable amount of statistical information is published regularly. Thus a careful study of the factors involved can lead to the development of a generalised model, the input for which is readily available. A brief description of the relevant aspects of gold mining is given below in order to illustrate the suitability of this field for computer modelling for investment analysis.

5.2. Gold mining operations commence with the sinking of a shaft from which tunnels are driven out at various levels to meet the reef containing the gold-bearing ore. The grade of ore (i.e., proportion
of gold to rock) varies throughout the mine. The minimum value of grade which can be mined profitably is known as the pay limit and is determined by the price of gold and by working costs. Three principal activities proceed more or less in parallel throughout the life of the mine:

- **Development**—in effect exploring the reef to determine the payable areas, known as the ore reserves.
- **Mining**—blasting the payable ore and hauling it to the surface.
- **Milling**—reducing the ore to gold metal.

The usual practice is to develop the mine in such a way that the proved payable ore reserves would take between about two and four years to mine. In this way mining operations can be carried out selectively so that the grade of ore mined is kept fairly constant. Once a mine is in full production the milling rate usually remains more or less constant. From time to time further shafts may be sunk so that new areas can be developed. Ultimately all the payable ore will have been mined and the mine will be closed down.

5.3. For any particular mine, working costs per ton of ore milled are usually very stable, with a slow upward trend induced by inflation. Working costs vary considerably from mine to mine as do their rates of change. Capital expenditure is very heavy in the early stages and fairly heavy from time to time at later stages when new shafts are being sunk or if unexpected difficulties are encountered (such as flooding). Generally speaking, capital expenditure is allowed as a cost for tax purposes.

From the above description it is evident that, for a given mine, since there is some measure of stability in the milling rate, ore grade and working costs and since the availability of regular information enables trends to be projected, a fair estimate of working profit can be made, at least in the short to medium term. Estimates of capital expenditure can usually be made from an examination of quarterly figures and from announcements by the mining companies. Tax can then be calculated and earnings estimated. It is normal practice to put some earnings to reserve so that dividend payments can be evened out, although for the benefit of shareholders most mines tend to pay out at a higher rate during the early years when tax allowances are large enough to obviate the payment of tax. Thus the earnings estimate can be used to arrive at a dividend forecast.
5.4. It is quite common practice to regard an investment in a gold mine as being somewhat similar to the purchase of a fixed term annuity. For the price of a share, dividends are received during the life of the mine, possibly followed by a capital repayment representing a share of the break-up value of the company. The dividends and break-up sum can then be discounted to arrive at a present value for the share, which can be compared with its market price.

5.5. Although the subject of valuation of gold mines contains complexities beyond the scope of this paper, enough has probably been said to indicate the general lines along which a computer model can be constructed. Under present conditions, with the future of the gold price particularly clouded, gold mine share analysis needs to be a dynamic rather than a static process. A computer programme which allows for a wide range of gold prices, combined with various assumptions as to the future rate of inflation of mining costs, becomes particularly valuable.

CONCLUSIONS

There is clearly much benefit to be gained by investment analysts from using computer/statistical techniques. The most useful application comes from studying particular classes of stocks and shares where a considerable volume of regular statistics need continual examination and routine calculations. For all these applications, the maximum attention must be given to the accuracy and reliability of the input data, which should preferably be as factual as possible with the minimum requirement for estimates of earnings and other factors which are difficult to quantify.
APPENDIX I

DERIVATION OF EXPONENTIAL SMOOTHING EQUATION

Suppose that the weight given to the latest data is W, and that the weights given to earlier dates decrease at 10% per period. Then the weight given to the one-from-last data will be 0.90W, and the weight given to the next data back will be 10% less than 0.90W (i.e., 0.81W) and so on. It is evident that the successive weights will be:

\[ W, 0.9W, (0.9)^2W, (0.9)^3W \ldots \]

or in general

\[ W, (1-\alpha)W, (1-\alpha)^2W, (1-\alpha)^3W \ldots (1-\alpha)^nW \]

where \( \alpha = \) smoothing constant.

This is a geometric series whose sum to infinity is given by:

\[ W, \sum_{0}^{\infty} (1-\alpha)^n = W/\alpha \quad \text{(if } 0 < \alpha < 1). \]

Now the sum of the weights in any system of averaging must equal unity, hence:

\[ W/\alpha = 1, \quad \text{i.e., } W = \alpha. \]

Thus, the exponentially weighted moving average at time \( t \) is given by:

\[ A_t = WD_t + W(1-\alpha)D_{t-1} + W(1-\alpha)^2D_{t-2} + \ldots \]

\[ = \alpha D_t + \alpha(1-\alpha)D_{t-1} + \alpha(1-\alpha)^2D_{t-2} + \ldots \]

where \( A_t = \) exponentially weighted moving average at time \( t \)

\( D = \) data for time \( t \).

For the previous period \( (t-1) \) it is given by:

\[ A_{t-1} = \alpha D_{t-1} + \alpha(1-\alpha)D_{t-2} + \alpha(1-\alpha)^2D_{t-3} + \ldots \]

Multiplying this expression by \( (1-\alpha) \) we get

\[ (1-\alpha)A_{t-1} = \alpha(1-\alpha)D_{t-1} + \alpha(1-\alpha)^2D_{t-2} + \ldots \]

which is the same as the expression for \( A_t \), but without the first term (\( \alpha D_t \)).

Hence we get:

\[ (1-\alpha)A_{t-1} = A_t - \alpha D_t \]

or, rearranging

\[ A_t = \alpha D_t + (1-\alpha)A_{t-1}, \]

i.e., \( \) New average = \( \alpha \) (current data) + \( (1-\alpha) \) (old average).
### APPENDIX II

**PERFORMANCE OF SYSTEM COMPARED WITH F.T. ACTUARIES INDEX**

**Table I—buys**

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<th>No. of signals</th>
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APPENDIX III

TV Rental Balance Sheet Simulation Programme

Name of Company:

XYZ Rentals Ltd.

Fixed Input Information as follows:

Company Year End Mar 1971

Straight Line Depreciation on Assets Below

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Rental operating costs last year. (£ mill) 6·000
Mono rental rev. as per last P/L account (£ mill) 10·000
Colour rental rev. as per last P/L account (£ mill) 5·000
Last year's interest charge (£ mill) 0·500
Tax payable on last year's profit (£ mill) 0·000
Wkg cap as per last B/S (£ mill) 2·000
Book value of rental assets (£ mill) 12·000
Tax equalisation reserve (£ mill) 1·000
Tax allowances and losses B/F (£ mill) 0·000
No. of ord. shares (mill) 25·000
Net add mono sets last year (mill) 0·025
Net add col sets last year (mill) 0·025
Value of net add of mono sets last year (£ mill) 1·500
Value of net add of col sets last year (£ mill) 5·000
First year of conversion 1974
Nominal value of convertible loan (£ mill) 2·500
Coupon (%) 7·000
No. of extra shares after full conv. (mill) 2·500

Variable Input:

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### The Computer for Investment Research

#### Financial Years

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<td>200.00</td>
<td>200.00</td>
<td>200.00</td>
<td>200.00</td>
</tr>
<tr>
<td>(DK) Mon sets scrapped (mill)</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
<td>0.03</td>
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</tr>
<tr>
<td>(DL) Col sets scrapped (mill)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>(DM) Non-rent prof (£m)</td>
<td>50.00</td>
<td>50.00</td>
<td>50.00</td>
<td>50.00</td>
<td>50.00</td>
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<tr>
<td>(DN) Non-set cap exp (£m)</td>
<td>1.00</td>
<td>1.10</td>
<td>1.10</td>
<td>1.20</td>
<td>1.20</td>
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<tr>
<td>(DO) Min int (% prof)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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</tr>
<tr>
<td>(DP) Rev factor mon</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>(DQ) Rev factor col</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td>(DR) Oth cap allw (£m)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>(DS) Marg op cost/set mon (£)</td>
<td>8.00</td>
<td>8.00</td>
<td>8.00</td>
<td>8.00</td>
<td>8.00</td>
</tr>
<tr>
<td>(DT) Marg op cost/set col (£)</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
</tr>
<tr>
<td>(DU) Cost inflation %</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>(DV) Set cost inflation %</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<td>0.00</td>
</tr>
<tr>
<td>(DW) Revenue inflation %</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>(DX) Fixed cost adj</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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</tr>
<tr>
<td>(EA) VAT % on rent charge</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>(EB) VAT % on opr costs</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>(EC) % of opr costs attract vat</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>(ED) VAT revenue factor</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>(EE) VAT rent charge adj factor</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>(EF) Payout ratio</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
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</table>

#### Results:

<table>
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<tr>
<td>(RA) Revenue</td>
<td>17,420</td>
<td>19,779</td>
<td>21,950</td>
<td>23,945</td>
<td>25,785</td>
</tr>
<tr>
<td>VAT incl VAT</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>(RB) Opr costs</td>
<td>6,600</td>
<td>7,185</td>
<td>7,750</td>
<td>8,286</td>
<td>8,785</td>
</tr>
<tr>
<td>VAT</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Opr costs incl VAT</td>
<td>6,600</td>
<td>7,185</td>
<td>7,750</td>
<td>8,286</td>
<td>8,785</td>
</tr>
<tr>
<td>(RS) VAT payable</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>S.E.T. adj</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>(RC) Pre-dep prof</td>
<td>11,021</td>
<td>12,794</td>
<td>14,400</td>
<td>15,858</td>
<td>17,200</td>
</tr>
<tr>
<td>(RD) Depr costs</td>
<td>4,135</td>
<td>5,450</td>
<td>6,888</td>
<td>7,088</td>
<td>7,371</td>
</tr>
<tr>
<td>(RE) Pre-int prof</td>
<td>6,885</td>
<td>7,344</td>
<td>8,012</td>
<td>8,770</td>
<td>9,285</td>
</tr>
<tr>
<td>Int charge</td>
<td>0.370</td>
<td>0.204</td>
<td>0.310</td>
<td>0.888</td>
<td>-1,254</td>
</tr>
<tr>
<td>Non-rent pre-tax prof</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>(RF) Pre-tax prof</td>
<td>6,514</td>
<td>7,139</td>
<td>8,322</td>
<td>9,658</td>
<td>11,353</td>
</tr>
<tr>
<td>(RG) Tax</td>
<td>2,606</td>
<td>2,806</td>
<td>3,329</td>
<td>3,863</td>
<td>4,541</td>
</tr>
<tr>
<td>(RH) Net prof</td>
<td>3,909</td>
<td>4,284</td>
<td>4,993</td>
<td>5,795</td>
<td>6,812</td>
</tr>
<tr>
<td>Minority interests</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Pref div</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>(RI) Attr to ord</td>
<td>3,909</td>
<td>4,284</td>
<td>4,993</td>
<td>5,795</td>
<td>6,812</td>
</tr>
<tr>
<td>(RJ) Earnings/share</td>
<td>15.6p</td>
<td>17.1p</td>
<td>20.6p</td>
<td>23.2p</td>
<td>27.2p</td>
</tr>
<tr>
<td>(RO) Earnings/shr conv</td>
<td>15.6p</td>
<td>17.1p</td>
<td>18.2p</td>
<td>21.1p</td>
<td>24.8p</td>
</tr>
<tr>
<td>(RK) Gross cash flow</td>
<td>8,044</td>
<td>9,733</td>
<td>11,382</td>
<td>12,883</td>
<td>14,183</td>
</tr>
<tr>
<td>(RL) Cash flow/shr</td>
<td>32.2p</td>
<td>38.9p</td>
<td>45.5p</td>
<td>51.5p</td>
<td>56.7p</td>
</tr>
<tr>
<td>(RM) New mon sets rented</td>
<td>1,171</td>
<td>1,121</td>
<td>1,500</td>
<td>1,700</td>
<td>1,700</td>
</tr>
<tr>
<td>(RN) New col sets rented</td>
<td>6,862</td>
<td>6,418</td>
<td>5,900</td>
<td>5,945</td>
<td>5,981</td>
</tr>
<tr>
<td>Tax payable</td>
<td>0.231</td>
<td>0.413</td>
<td>1.137</td>
<td>1.923</td>
<td>2.717</td>
</tr>
<tr>
<td>Ord dividends</td>
<td>1.954</td>
<td>2.142</td>
<td>2.497</td>
<td>2.697</td>
<td>3.406</td>
</tr>
</tbody>
</table>
REFERENCES


5. Financial Analysis Program, edited by IBM.


SYNOPSIS

Three reports made to the International Congresses of the European Federation of Financial Analysts Societies on the development of investment analysis by computer are discussed in Part I. The 1966 and 1968 reports were mainly concerned with processing investment statistics, pricing individual shares or selecting portfolios by mathematical means. By 1970, however, some of the more elaborate schemes for pricing equities and selecting portfolios had been abandoned, more emphasis being given to data processing of investment statistics and to analysing by computer special categories of investments where a considerable volume of regular investment statistics are available and extensive calculations are required.

The authors then proceed to describe two practical computer applications dealing with specialised classes of share. Part II deals with the application of simple statistical techniques to investment trust shares in an attempt to select those that are "cheap" or "dear". The suggested method, tested for the first nine months of 1971, showed that the shares recommended as "buys" recorded a gain of 4.1% better than the investment trust index, whilst the "sales" underperformed the index to the extent of 6.8%.

The finances of the television rental companies have distinct analogies with those of a life assurance business. TV sets have a life span like a mortality experience and their installation costs involve a new business strain; Part III demonstrates how a computer model of a TV rental company can be used to assist the analyst in forecasting future profits, allowing for likely changes in costs, taxes, etc. Similar techniques are, in fact, applicable for the analysis of South African gold mining shares which form a homogeneous group with a considerable volume of regular statistical information (see Part IV).

The authors conclude that these computer applications, whilst requiring much further research, offer considerable prospects provided that accurate, reliable and specific input material is available.
DISCUSSION

**Mr. J. Plymen**, introducing the paper, said:—In order to bring the historical references up to date, I would draw Members' attention to the latest Institute paper by Professor Moore submitted on the 28th February on the use of mathematical models for selecting portfolios. This paper dealt in detail with the progress made so far with Markowitz techniques and with certain modifications to them: techniques for maximising the returns allowing for the degree of risk. I think Professor Moore really agreed with me that this Markowitz principle, as originally propounded, imposes impossible demands on the analyst. However, he discussed various modifications of this principle designed to make these systems rather more practicable.

In Part I of the paper we refer to various schemes using multiple regression analysis to price individual shares. I was very interested to discover during my recent visit to South Africa that Mr. Willem Pretorius, a Fellow of the Faculty who trained in Edinburgh some fifteen years ago, is experimenting with a share evaluation model using a regression programme covering 100 shares in the South African market. Preliminary results for this model appear very favourable with the underpriced shares performing some 20% better than those that are regarded as overpriced. It is possible that in the less sophisticated market of South Africa, much less affected by the activities of investment analysts and performance-seeking investment managers, these regression techniques may produce better results than they do perhaps in U.K. or U.S.A.

In Part III we describe in detail our computerised model of the TV rental industry. I would like to stress that the technique used, deriving a formula for earnings per share based on various assumptions as to the progress of the industry, is of perfectly general application to other industries where we have a homogeneous group of companies and adequate statistics regarding output and costs and so on.

Finally, I would like to repeat what we said in paragraph 3.12 of the paper that certain statistical aspects of both the control chart system and the regression analysis need closer investigation. This is really rather an understatement. The fact is that the statistical treatment of time series is really on the frontiers of mathematical research and leading exponents are still arguing about the validity of certain techniques in different circumstances. At any rate, whilst our methods may have certain weaknesses to the statistical purist, we maintain that they appear to work in practice!

**Mr. P. J. Derby**, opening the discussion, said:—In writing this paper, the authors have covered for us in synopsis form the main trends of computer usage for investment research and have examined in varying detail three areas of application. As we see from the paper, the two main streams of development, both in the United Kingdom and in the United States, have been on the one hand towards data processing of statistics and the other towards techniques of share selection. It would appear that the authors' preference lies in the second area and, in particular, to specific groups of shares for which statistics are available and analysis is possible.

While not disagreeing with the authors that the examples they have chosen are of interest, I consider it important that in the discussion on
The Computer for Investment Research

the first paper to the Faculty on the use of computers for investment research some emphasis should be placed on aspects of the data processing of investment statistics for, in my view, it is in these areas that the largest strides have been made in recent years. To many actuaries not on the investment side this may appear dull by comparison, but it should be appreciated that investment statistics are copious, requiring careful handling and presentation. The investment decision is such a difficult one and subject to so many uncertainties that it is doubtful if any technique which is entirely scientifically based and thus capable of being computerised can beat the market. Thus, it is my firm's view that as much science and computer power should be brought to bear not only on the investment information available but also on the portfolio under management, leaving the final decision as to buy, sell or hold to the investment manager.

My firm's experience has been confined to the area of U.K. equity investment where, as far as I am aware, the most advanced computer applications of the data processing type have been developed by two stockbroking firms, Hoare & Co., Govett, who offer an extensive range of computer services, and, in a more limited and selective way, ourselves. Perhaps you will forgive the "Avis" of the industry opening the batting as for once we have territorial advantage.

In this context, I would like to mention as examples two areas of research in which we have found the computer's number-handling ability invaluable. The first of these is called "relative value and relative strength". This relates the price, dividend yield, earnings and price-earnings ratio for either an individual share or sector to the average market values at the same date of these statistics as measured by the Financial Times-Actuaries Indices. The computer is used in storing historical data for each share and the indices from which the relatives are calculated. Of particular use to investors is the ability of the more sophisticated computer equipment to graph the information in the form of relative charts.

The second example is called financial analysis. As the name suggests, the computer is used to calculate the many financial ratios which are used by the investment analysts to assess the financial strength of a company. Again, most of the calculations are basically simple, but the speed and flexibility of the computer allows an extensive range of ratios to be calculated in a uniform way. From the Profit and Loss Account and the Balance Sheet the computer can construct a Source and Use of Funds table which is of particular interest when studying the financial development of a company. Further, the contribution to change of earnings coming from change in margins, change in capital utilisation or other changes in the financial structure, can be broken down. As an additional bonus, it is possible to aggregate data for several companies within the same industry in order to establish an average against which each of the companies can be compared. This is of considerable use in homogeneous sectors such as Stores or Breweries.

Although not strictly investment research, the computer has useful applications in valuing portfolios and comparing the weightings of the holdings with the weightings in the Financial Times-Actuaries All Share Index. By this means, the exposure in any share or sector can be compared with the market and any relative variation either rationalised or altered by investment action. As an extension of this application, the overall performance of the portfolio over a period can be measured against the F.T. Index and the contribution to this performance broken down
The Computer for Investment Research

as coming from share and sector selection together with the results of switching.

Having briefly mentioned some of the wider uses of computers for investment, I should now like to comment on some of the more detailed applications covered by the authors. On the section on investment trusts, the authors propose two methods of selecting investment trust shares. The first attempts to rationalise the status of a trust as measured by its discount with various fundamental criteria by applying a multiple linear regression analysis programme. From the coefficient of the regression equation, it can be seen that the most important of the criteria is the five-year management rating which is given four times the weighting of the gearing and seven times the weighting of the dollar percentage. The equation indicates that a 1% variation on the five-year management rating justifies a 1½% change in the discount, which is surprisingly low given the wide disparity of discounts ruling in October 1969 of the order of 35%. In a similar type of analysis that we have carried out at approximately the same time, using a linear regression between our own five-year plus management ratio and the discount, we found that 1% variation in performance was equivalent to no less than 4% in the discount. Thus, although the authors have allowed for gearing and U.S. percentage, I find it hard to understand the low weighting to performance brought out in the authors' equation. In our experience, the weightings given to management performance varies with time from a maximum of 4½ in April 1970, at which period the actual performance of most trusts was turning down, to the current weighting at 1½ reflecting the poor performance over the last two years. This highlights problems in the methods proposed by the authors in that some predictive criterion is required which it is difficult to build into a computerised system. Nevertheless, the exercise at least tells a researcher more about the market in which he is investigating.

The second method is entirely confined to trust price movements relative to net asset values and could be described as technical analysis. When the discount is sufficiently out of line with past experience, as measured by a multiple of the mean absolute deviation, then a "buy" or "sell" signal appears. The authors' experience with analysis along these lines has been more successful, though care should be exercised in interpreting their results as there appears to be no attempt to rate the performance to a time scale. It is not surprising during a bear market when discounts are generally widening (the range typically is 15-20% against 10-15% in a bull market) that the sales are considerably more successful than the purchases. It may be worth while applying the authors' methods to relative discounts, i.e., the actual discount less the average discount for all trusts on the same day, which should remove the general trust market movement. In any event, the practical application of this second method, I would have thought, was limited to a small actively-managed tax-exempt fund.

I have little to add to the section on profit forecasting for TV rental companies except to say that the computer application suggested appears very useful in what is a laborious and time-consuming job. In particular, the flexibility of the conversational mode is attractive to the analyst.

Finally, I would like to mention two computer applications for investment research in which I have been personally involved. The first of these concerns the analysis of proprietary life companies, though the same methods could be applied to mutual companies. From Schedule V of the Returns to the Department of Trade and Industry, it is possible to obtain a reasonably detailed breakdown of the liabilities of a life company. This
information can be stored on a computer together with the appropriate life tables. By applying valuation formulae and using interest rates and expense loadings as variables, valuations can be performed on any basis required. Considerable ingenuity is needed in allowing for the differing methods of grouping policies, which vary from company to company. In checking the results using the company's stated valuation basis, we found the valuations, as performed by us, varied at most 2% from the company's published results for the major classes of business. This gave us confidence in the valuations on our own basis which assumed market rates of interest, up-to-date expense loadings and mortality tables. No allowance was made for future bonus and the resulting difference between assets at market values and the liabilities valued on our basis represented the present value of the future profits, including bonus loadings, to emerge from the business existing at the date of valuation together with the estate. Splitting out the shareholders' interest and adding on an assessment of their not inconsiderable interest in the future business, we arrived at a mutualisation price for each company which, if tentative in absolute accuracy, gave a reasonable method of fundamental comparison between companies.

The second application is the use of the computer in the assessment of the relative merits of a convertible and the equity. The question can be posed: Assuming an investment in the equity is desirable, is it more advantageous to buy 50,000 ordinary shares or to pay more for the equivalent amount of convertible which can convert to 50,000 ordinary shares and obtain a higher immediate yield? The answer depends on whether the actual premium on the equivalent price through the convertible over the market share price is greater than or less than the discounted value of the extra income as a percentage of the ordinary share price. Given the prices, the theoretically correct premium is a function of the discounting rate, the growth rate of ordinary dividend and the tax rates of the investor, all of which are variables, together with the conversion terms and the allowed conversion dates, interest and dividend payment dates which, in contrast, are fixed for most convertible issues. The permanent data is stored for each convertible and the theoretically correct premium can be calculated by the computer under any set of variable assumptions. In particular, an interesting part of the programming is to arrive at the date at which conversions should take place. This is governed by the growth rate assumed for the ordinary dividend. Clearly the faster the growth rate, the earlier conversion is likely to take place, always assuming that the first date at which more income would be obtained by converting than holding the convertible falls within the allowed conversion dates.

On the front cover of the Investor's Chronicle reference by the authors, there is a picture showing a computer printed circuit board alongside a pile of pins and headlined, "Computers and Pins". I am sure that the authors' paper will have convinced many that pins are insufficient tools for the complex investment world of today and we are grateful to them for providing a platform from which the use of computers for investment research can be explored.

Mr. D. M. Simpson:—I would like to refer back to some of the seven categories of computer projects mentioned in paragraph 2.1 of the authors' paper.

Category I deals with the pricing of specific equity shares. As I understand it, the idea here is to devise some method of analysing historic data—whether of prices, dividends, earnings cover or whatever—with a view
to predicting future price movements of shares and hence to producing a
list of shares which are cheap and should be bought and another list of
shares which are dear and should be sold. This is all very well as far as
it goes, but I have always found difficulty in seeing how to carry this into
practice. The investment manager has first to eliminate all shares in
companies whose market capitalisation is too small for him to be interested
in and then all shares in which he already has a large enough holding.
Clearly, these can both be allowed for. He is then left with a list of shares
which the analysis indicates should be bought and at this stage the invest-
ment manager will want to start using his judgment and, from his studies
of the fundamentals of the company, eliminate shares which he does not
want to buy; but this may be the wrong thing to do. These may be the
very shares from the selection of cheap shares which would be the most
successful and without them the other shares may not perform any better
than average. It seems to me that one has to persuade investment
managers not to exercise their own judgment at all once the modus operandi
of the system has been set up and that, I think, no investment manager
is going to allow.

One other point I would like to make about such pricing models is that
they must, of course, allow for the expenses of buying and selling. The
subject of Category III—selecting the best share portfolios—was discussed
recently at the Institute, as Mr. Plymen has mentioned. Reference is
made in Professor Moore's paper to this subject of transaction costs. He
shows there that supposedly optimal portfolios are often not in fact any
better than the existing portfolio if due allowance is made for the costs
of making the necessary changes.

The use of the computer for purposes in Categories I and III involves
the elimination of the investment manager's judgment to a large extent
and for that reason, I think, these models appeal more to the academic
than to the practical investor. I would be interested to hear of anyone
who has consistently used such models for the practical running of an
investment fund. I would agree with the authors' remark in the Intro-
duction that the most useful and profitable use of computer applications
for investment analysis lies in the study of certain specific groups of shares
and stocks, for the investment manager can use the computer models for
these groups, suppressing his judgment, and bring this into full play in
the rest of the portfolio where he has no computer model to tell him what
to do.

The investment trust analysis which the authors describe is an example
of Category IV work. I take it from their list at the end of the Intro-
duction that the other sectors that would fall in this category are con-
vertibles and mining finance houses. In the case of the former, presumably
the authors would envisage an analysis of how the premium over the
ordinary share price has moved historically—much along the lines of
movements in the investment trust discount that they describe. For this
particular case, I think I would have a preference for comparing the price
of the convertible with the price of the ordinary shares after taking into
account the likely dividend and interest payments and the appropriate
levels of income tax for the potential investor. Of course, as Mr. Derby
has described, the use of the computer is desirable for this also and maybe
this was in fact what the authors had in mind. Warrants, while more
complicated, lend themselves to similar treatment.

Many finance houses can be analysed in a similar way to investment
trusts in that, to a large extent, that is what they are with their large
holdings in quoted mines. What the computer model cannot do is to
include an exact value for the exploration interests of these groups. A substantial nickel or copper discovery will cause a much greater short-term variation in share price than is ever seen in investment trust prices.

It seems to me that the use that appeals most to the investment manager is Category V. Here we have a model, whether it be of a TV rental company or a gold mine, into which can be fed whatever values of the various parameters is desired. The investment manager is able to see the results of various different assumptions and he has the facility to enable him to change his mind. As the authors state in paragraph 5.5, such models must be dynamic and not static.

The authors say little about Category VII which they describe as fundamental research usually undertaken by university economists. If I understand this correctly, it is similar to Category V except that one starts further back by considering what economic, fiscal and technological changes there will be in future influencing, for example, the sales and rentals of television sets. This means, perhaps, building an econometric model of the country and getting data as output which is the variable input to the TV rental model mentioned in Appendix III. The authors do not indicate how they have made estimates of these input items, although they refer in paragraph 4.1 to the fact that estimates can be made.

I was interested in the fact that the authors rejected their original investment trust model on the grounds that it did not give results which were correct in the sense that they were justified by subsequent share price movements. As they state, it is no use being the only man in step. You either have to persuade everybody else to your way of thinking or abandon the idea, at least temporarily. This is, I think, a vital reminder that the object of investment research is to get better information before the next man: it is no good if the next man never gets it.

Mr. J. B. Marshall:—To me, the most fascinating part of this enjoyable and, happily, comprehensible paper is the opportunity it gives us to study the contrast between the two approaches to investment: between the fundamental and technical, as it has been called, between investment and the money game and, I am tempted to say, between sense and nonsense. Before returning to this theme, I would like to point out some gaps in the authors' analysis of investment trusts in the hope that they will fill them up in their reply to the discussion.

The first of these is that it is not stated how the assets of the investment trusts are calculated. There is an implication that the prior charges have been deducted at par. If so, I would suggest that that is contrary to most people's thinking at the moment and it makes no more sense than taking the assets at par, where this is relevant.

The second thing is that I am not quite clear from the paper what has been done about the 25% surrender role. I hope that this will not matter after tomorrow, but I certainly think it affects the regression analysis which the authors have done.

The third point is, for the benefit of those of us who are unable or unwilling to consult an ancient Investor's Chronicle—could the authors please confirm that this investment performance is a five-year terminal-to-terminal measurement?

I would like to contrast the results, as Mr. Derby has done earlier, with some investigations of a similar nature which I have done in the past. The first point I want to make is that, when I did this, taking 75% of the dollar premium produced a positive correlation coefficient—or in this case a negative coefficient—similar to the authors', but when the 100% was taken in, this correlation disappeared altogether. The second difference
was that gearing appeared to contribute nothing to the regression equation, a fact which makes sense to me because gearing is something which can be put right at a stroke of a pen by investment trust management whereas the percentage in dollars can not. A third difference was that I used a totally different method of measuring performance and I would like to come back to this in time. The result of this was, as in the case of Mr. Derby's investigation, that the coefficient of $X_1$ came out at something like 5. Whether this is different—so markedly different—from the authors', I am not quite clear; one may have to multiply their coefficient by 5 to get a comparable basis. The other difference, I am happy to say, was that on this basis I did find, for a limited period, positive predictive results, but using a method based on price relatives rather than on discounts or relative discounts. The trouble with following discounts is you can be right about their course and still lose money because the underly­ing policy of the trust turns out to be wrong.

Looking to the future, I think there are three questions one has to ask. Firstly, is it reasonable to expect good performance to be continued? Secondly, is it reasonable to expect discounts to move in the way the authors have described? And, thirdly, why do we get poor results from the fundamental approach and good results from the technical approach?

Taking the last one first, it can mean one of two things. Either there are a large number of trusts which oscillate between being dear and very dear without ever getting to a sensible price and, similarly, a large number of trusts which oscillate between being cheap and very cheap. The second possibility is that the measure of performance which they have used is inefficient in the sense that it fluctuates too much from year to year. This could well be true because of the great effect of policy on the performance of an investment trust over a limited period. Thus, for instance, one which is heavily in the United States might look terribly clever at one particular date and not nearly so clever a year later.

My view is that good performance, once established, will be continued, but this is a subjective judgment based on a feeling that people either follow sensible methods in this investment game or they don't and those that make mistakes have fertile imaginations in dreaming up different mistakes to make from year to year. Somewhere I have seen a calculation that the standard deviation of the performance of individual shares in a year is 25%. This means, I think, that for a fund of 100 stocks the standard deviation of a performance will be 2½%, which is quite substantial: this, in turn, means that you have got to examine the performance of an investment trust over a longer period, I would suggest, than five years before you can reach any firm conclusion.

Coming back now to the second question which related to the sense or otherwise of the authors' examination of the course of discounts. Chartism, of which this is an example, must depend on the existence of insider information or a gradual change in the conventional wisdom on any particular stock. The first point, insider information, is clearly irrelevant in this case: I think there may be something in the second but, quite clearly to me, this investment trust field and this movement in discounts is ideal ground for a random walk.

I would like to close by making two points. First, as this paper is about computers, I wonder, even if one accepts the authors' technical method, whether a computer is necessary to produce the answers. It seems to me that a quill pen would be more efficient and it would certainly be quicker. The second point is that it is disappointing to me that the authors have abandoned so easily and so uncharacteristically an approach
which seemed to me to be full of common sense in favour of something which savours of magic. I would urge them to think again about this, to sharpen their techniques and see whether this could produce better results.

Mr. T. D. Kingston.—I would just like to give two examples which have happened in my experience where, while we did not use computers, the technique in use would have lent itself to this. The first was in using a model to predict industrial equity profits, given varying rates of inflation and growth, as part of a study of relative yields on property, equity and fixed interest. The model was based on projecting sales, trading margins and all financial charges for standard companies. At high rates of inflation, assuming also a change to inflation accounting, the projections for industrial equities were black in the extreme. This was because trading margins had been on a falling trend for a long period and our projections carried on this trend. Some of the results were alarming. The assumption must be that margins will not, in fact, continue to slide, or at least not at the same rate as they have done in the past. So, effectively, while finding the model interesting, we refused to believe it.

The second example has been alluded to by both Mr. Derby and Mr. Simpson. This is the use of compound interest formulae to relate convertible and equity prices. This has been extended to a considerable degree by stockbrokers and institutions in recent times and we have done some work on this ourselves and have done a certain amount of switching on account of it. One of the problems that we have found was that, having switched from the equity into convertible (which has generally been the way), we have later on decided that the share itself is fundamentally too dear: we have tried to sell the convertible and have found that the marketability of the convertible has been so bad that we have lost all the gain that we made originally.

What I am basically saying is that the computer has tremendous uses in this type of application but we must be well aware that the fundamentals can throw the whole thing awry. The computer is only one tool of analysis; it is not a complete answer.

Mr. G. M. Murray.—I think our thanks are due to the authors of tonight's paper as it focuses attention on the fact that computers have reached the stage of assisting management in decision making and should no longer be treated as merely glorified Hollerith machines.

The first section of the paper reviews the development of investment analysis projects by computer. For an investment manager, portfolio selection attracts immediate attention, and while the application of the Markowitz principle is impossible in practical terms at the present time, it should, nevertheless, be every bit as much required reading as "The Money Game", Cairncross or Rose—these are in random order of priority. However, I look forward to studying the work which is being done in this area using linear programming techniques. A fairly comprehensive forecasting system is again required, but since the forecasting is basically what is presently being done on an individual basis when selecting shares, (or at least what should be being done) it only requires extending to a limited number of choices at any given moment of time and I am sure we shall be seeing encouraging results before too long.

Part II and its analysis of investment trusts highlights the immediate benefits which are possible by the intelligent use of computers. It is disappointing that the regression analysis applied both here and earlier
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by Messrs. Weaver and Hall to forecast share prices have not yielded more fruit. There is a feeling amongst academics that regression analysis should be successful to a high degree of accuracy in most forecasting situations, given the time and application and assuming the proper causal factors can be identified. I am sure this area should not be given up in spite of the disappointments so far and although it may be like the alchemist’s dream perhaps I should also point out that I still have faith in gold. However, where the item to be forecast is related to some standard which can be independently evaluated, then the method described in the paper in respect of investment trust share prices has general application. The authors have mentioned a number of these but the early work in this vein described in J.I.A. 90 by Mr. Pepper could probably be taken further. Marketable debentures relative to gilt-edged stock or index is another possible application and the assessment of property share prices relative to asset value, which itself (the asset value) is built up by a computer method, is another. It is the principle which is important and as it could also be used to form part of the TV rental company model for forecasting sales or expenses, this leads to the next section dealing with the construction of these models.

Both in the Faculty of Actuaries and in investment departments, we are going to hear a lot more about this work. The model described by the authors is a relatively simple one, but in all industries there are companies at varying stages of developing computer based models of their total operations, from sales forecasting to profit and loss account, balance sheet and cash flow projections. Perhaps a certain amount of industrial espionage will be required before they come into general use by investment analysts, particularly where the more complicated manufacturing companies operating on an international basis are concerned, but it certainly won’t stop at TV rental companies or gold mines. The cost of constructing these models escalates dramatically as a more perfect solution is sought and while some consultants suggest that acceptable accurate results can be achieved at ridiculously low cost a worthwhile model would justify considerable expenditure.

This paper has concentrated on investment projects, but its relevance to the Faculty is mainly in the techniques it has demonstrated, all of which can be applied by management generally, given the necessary statistical base from which to begin. The compilation of this data base will be worthwhile in itself, but since we as a profession have always been interested in statistics I think consideration should be given to broadening our statistical studies to include not only their application to calculating life premiums and valuing life assurance liabilities but also their application in the wider field of operational research techniques relevant to managing any company or project.

Mr. G. M. Dobbie, closing the discussion, said:— I would firstly like to express my appreciation to Messrs. Plymen and Prevett’s Introduction in Part I describing briefly the 1966, 1968 and 1970 Reports to the analysts’ societies. This précis is supplemented by comments on the developments in 1971 indicating that the trend to use computer facilities in the authors’ Categories IV and V was continuing.

Mr. Simpson has discussed Categories I and III and his comments were supplemented by Mr. Murray on Category III. Category II projects use computers to screen data. A truly vast amount of data is required here but there has been progress in both U.S.A. and Great Britain. In fact, an American bank has estimated that the use of such projects could save
20% of their analysts' time. One danger here is that subtle differences in accounting practices may not be so apparent to an analyst as they would be when working from basic sources. The figures may not, in fact, be comparable. Nevertheless, such projects are definitely useful.

There have been several attempts in the technical analysis field—the authors' Category VI—as they state. This I would express as the forecasting of relative trends and hence medium-term price movements.

I would like next to make two general points on the investment trust study. Firstly, if the trusts were to make more extensive use of warrants, perhaps in the raising of fresh capital, some difficulties could arise in making comparison between trusts. Secondly, the detailed history of the discount based on actual monthly valuations is still fairly short and the extent to which it is affected by the current capital gains tax rules not entirely clear.

Proceeding to the authors' time series analysis of the discount data, it is apparent that there are fairly large short-term fluctuations about the trend; the objective is to determine a suitable level in the fluctuations which is a signal to buy or sell. Fortunately, perhaps, I would not expect all investors in this market to be pursuing this objective all the time. A portfolio manager following a system such as this would have to be quite clear as to his overall investment objectives and the extent to which such a system was an aid. Anomalies do arise in markets and will continue to do so. The graphs in the paper show that the anomalies in investment trust discounts are corrected by market forces within comparatively short periods, suggesting that present investment services are not altogether inefficient.

The television rental industry is well suited to the actuarial approach and has been dealt with very ably in the paper. The industry does experience technical developments from time to time but has shown itself able to live successfully with change. The computer is well adapted to carry out the calculations which enable the results of various assumptions to be seen rapidly.

In the section on South African gold mines, the authors indicate the general lines which could be followed in constructing a computer model to project and compare profitability in gold mining. I look forward to studying the treatment of the unexpected difficulties, and I quote, "such as flooding".

In concluding, I would like to make a few general remarks—not aimed, I hasten to add, in any particular direction. It will be most profitable if those setting out on computer applications remember that the end result must be such as will enable some portfolio managers to meet their investment objectives. The investment problem is a mixture of economics, psychology and mathematics. Within this framework, the computer can be of most use where the mathematical content of the problem is a major part. The mathematical foundation of the TV rental business is clearly suitable. It might be thought that there are dangers where economics is a major part of the problem but I would suggest that here the ability of the computer to repeat the calculations rapidly with different inputs will, in fact, serve to show the range of earnings progressions which could occur. The area of investor psychology, I would suggest, includes fashions for companies or even whole sectors and I can certainly see that computer application could make explicit investor sentiment and changes therein. Whether forecasts of changes in investor sentiment will be justified is, however, another matter.

I believe that Mr. Plymen and others involved in computer applications
often regret that details of all other computer applications are not made public. There is therefore all the more reason for us to thank Messrs. Plymen and Prevett for presenting their work to us tonight.

The President (Mr. J. Young):—I was interested in the authors' analogies between the TV rental business and the life assurance industry and have been wondering whether in life office practice we should not be considering procedures similar to those suggested by the authors and developing models for judging the future profitability of life assurance companies and long-term insurance business, because the principles seem similar. The precise facts of the life assurance assets and liabilities are known at every valuation date and these constitute the fixed input. It seems quite rational to transform the assets and the liabilities in each case and as a whole into future time series of receipts from assets and of payments from outgo less receipts from premiums: it cannot be denied that in practice that is exactly what they are and yet we are fairly accustomed to looking on these two items as single figures of present values. The actuary has, of course, to exercise his judgment about certain elements that come into these time series and then constitute the variable input. In the assets series, he has to decide what the future rate of growth of equity dividends may be: on how much of the income and the capital he can rely in the case of non-risk-free investments: on the dates for redemption of securities where there are optional redemption dates. On the liabilities side, he has mortality, and he may wish to consider whether that should be varied according to the nature of the liabilities between full premium and low premium business, between female and male lives assured and whether he should allow for improvement over the future. He has to judge on the rate of inflation to allow realistically for expenses: on the rate of interest and the bonus reserved. He may wish even to introduce withdrawal rates into the calculations. All these are and always will be the problems for the actuary, but with models such as have been described this evening, in particular the one for the TV rental business which, to use the authors' words, is "linked to a computer terminal and which is in the conversational mode", it would seem to me that it would be a practical and a useful aid, not only in helping to form the actuary's judgment but also even perhaps as a bonus in coming to friendly terms with these machines.

I have enjoyed the authors' paper this evening. I think both authors may wish to deal now with some of the points arising from the discussion and I now ask Mr. Prevett to reply in the first instance.

Mr. R. M. Prevett, replying to the discussion, said:—First we should like to thank you for the attention you have given to our paper, and for the interesting points which have been made. It is difficult to do justice to these points in a verbal reply; however, I would at this stage like to make a few brief comments.

Mr. Marshall enquired about the management rating used in the regression analysis. This was the average annual percentage gain of the trust compared with the F.T. Actuaries Index over a 5-year period.

Several speakers regretted that the regression analysis approach was dropped so early. The reason was that at the time we felt that the technical approach was likely to prove more rewarding. However, we agree that there is scope for further research using regression analysis, and we hope to be able to continue work in this direction.

Mr. Derby described some work which had been carried out on convertibles. Although not mentioned in our paper, we have done some
research into the valuation of convertibles, and have produced a computer model which is being run on an experimental basis. The principle is to find a price for the convertible such that the present value of the interest payments until conversion is equal to the present value of the equity dividend payments plus the present value of the capital gain in the equity, assuming a given dividend growth rate and assuming the capital value gains at the same rate.

Mr. Marshall raised the point as to whether the use of a computer was justified in the method we use to analyse investment trust shares. In this connection it may be of interest to know that the cost of producing a weekly analysis is in the region of £1 or so.

Mr. J. Plymen, replying to the discussion, said:—Mr. Derby described in some detail his own data processing techniques and, as we said in the paper, we have a very high regard for this type of computer application. I am more familiar with the Hoare & Co. system as I have seen that in some detail and there is undoubtedly a tremendous service to be provided to the investment community by suitable processing of the statistics. However, I feel this has to be done with great care. Firstly, in doing a major and comprehensive study whereby one works out all sorts of ratios and looks at the balance sheets and the cash flow and all that kind of thing, it is very easy, in the tremendous effort that is involved in putting together all this material, for the quality to deteriorate. I think it is an absolutely vital point in any computer application that the material you put in is as absolutely reliable and consistent as it can be. If it is done on too wide a scale, I think various problems of consistency and accuracy are liable to creep in. A further problem is that the output gets so big. You get such a tremendous mass of figures. There is a certain amount of risk that these widespread data processing applications will result in the unfortunate investment managers being provided with so many figures that they do not know what to do with them all. I think that it is most important in all these schemes that, rather than produce vast sheets of tables and ratios and, masses of charts, there should be a most careful filtering system so that the selection of the important part of the data is done by the computer and does not have to be done by the unfortunate recipient.

I remember some years ago visiting a famous American bank and they were very proud of their computer work and they were feeding in the data tapes and calculating every possible ratio: there was a room about as big as this and all along one side there were papers up to the ceiling—it was the computer output on fanfold paper and it was all piling up and they just did not know what to do with it all. They got far too many ratios and far too many figures with the minimum of favourable results.

Mr. Derby, again, referred to the use of the computer for working out the mutualisation prices for a proprietary life company. His technique is similar to what we use ourselves, but I must admit we have not really found it necessary to use a computer because the number of proprietary life companies is so small and, on the whole, tends to decrease. Also I think that within the proprietary life assurance industry one should be able to have a model into which you feed the various trends and premiums and growth of funds and so on, and produce projections of the profits. This is something which we are working on ourselves.

One of the speakers pointed out that we have not made much reference to the fundamental work carried out at universities. Well, I must admit, I am usually rather averse from these university chaps. These people always collect a great amount of data, getting it in a rather raw state
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from 500 Exchange Telegraph cards (or, in America, they take it straight off the data tapes) and then they boil up all this information with a tremendous amount of programming and computering and expenditure of time, eventually coming to the conclusion that investment analysts and stockbrokers and people like that are wasting their time. I take the view myself that these university-trained statisticians who play about with this financial data ought to learn more about the stockbroking and the investment and analytical aspect before they start. Often, most of their conclusions we knew from the beginning. In other cases, their conclusions are vitiated because they have overlooked errors and inconsistencies in the data.

There were several references to the fact that perhaps we abandoned the regression technique too soon. Well, I am very grateful for your comment and very appreciative of your interest in this effort and I think that criticism is quite fair. At the same time, we were certainly disappointed that the regression system which, in this case, ought to work did not appear very successful. I have studied these regression systems (operated by various people) quite closely. I am very suspicious of the sort of regression system which needs to have fed into it a lot of estimates and so on—the sort of Bank of New York system whereby one has to feed in the estimates of future growth and so on—all that kind of thing is so difficult to get right that one often finds that one is devoting a vast amount of analytical effort to feeding into the computer a lot of material and the end result is not tremendously effective. There is also the basic difficulty with these systems that if the coefficients do change considerably then the whole thing falls down. With the investment trust regression, there is little doubt that the value put on the American component can change dramatically from year to year with the outlook for the American economy: it can be favourable in some circumstances and unfavourable in others. If the coefficients are such that an important one can change for external reasons like that, then it is obvious that rankings based on the regression are not going to be very successful. Nevertheless, I think that we probably did abandon the regression too soon. We should, I think, have studied perhaps rather better methods of measuring past performance. The difficulty all the time is the problem that one does not want to be "too clever for the market", as we put it. If the market is working on past performances obtained from the Investor's Chronicle tables, that Investor's Chronicle ranking (suspect though it may be) is going to be likely to have a certain amount of validity in the forecasts and if you go to a lot of trouble and devise a highly sophisticated ranking system which nobody else uses, it probably will not reproduce the market prices or be of much practical use.

Reference has been made to the question of portfolio selection. As Mr. Murray says, the idea of selecting a portfolio by computer is a marvellous thing: it is a real philosopher's stone and, obviously, a lot of effort has been devoted towards it. I must admit I am very doubtful whether we will ever get anywhere with these highly sophisticated risk models, as discussed at the last Institute paper from Professor Moore. This paper did in fact encounter a lot of criticism on the grounds that the author was rather too optimistic about the difficulties of inputting data and, although I try to look forward to the days when one has better methods of getting the inputs and so on, I think the idea of a mathematical model which requires (however you try and simplify it) some extremely difficult estimates of the risk factor is still very, very far away from achieving anything. When using the Markowitz techniques, I am very averse from the use
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of historical data on risks and relative price movements and so on. I can't help thinking, as a practising analyst, of how many companies there are where the past performance of the share price and the earnings and so on is going to be very different in the future because of obvious changes in the management following mergers and take-overs and all sorts of other things that have happened, and any sort of Markowitz technique which uses this past material, is I think, terribly suspect.

I have referred in several places in this paper and in my Congress paper of 1968 to the Lionel Edie linear programming system and this appeared to work extremely well. It is surprisingly simple and it is astonishing that more has not been heard of it since. The procedure is to combine the companies that you are studying, put them together as a great conglomerate, add up all the balance sheets and all the earnings and all that sort of thing, and then get the computer by linear programming to play with the whole lot so as to maximise certain aspects to produce a portfolio which gives the best growth of next year's earnings or the maximum underlying assets or maximum interest in overseas trade or the maximum liquidity or something like that; all for a minimum of cost. I think this is an area where there is much scope for further research.

References have been made frequently to convertibles and, as my colleague says, we have done a lot of work on that ourselves. However, we need to test the routines for some time until we are completely sure of them so that we are not yet in a position to publicise the procedures in detail: but there is no question that it is now possible to evaluate convertibles with a considerable degree of science using the computer. Again, the warrant study—without the computer, one is just gazing into space, but the computer does enable you to bring together the various essential factors and, here again, you have a further problem: you may develop a highly scientific method which won't reproduce the sort of market valuations and won't discriminate between cheap and dear warrants. Still, it is a subject worthy of further study.

The President (Mr. J. Young):—I think you will agree that we have had before us this evening a very useful and a very practical paper and, while the number of contributors has perhaps been just a little smaller than we normally have, I do not think the authors need be too anxious on that account because it has been my impression that the quality and content of the contributions has been considerable, and I have no doubt the authors will wish to consider those at their leisure and reply in writing.

We are therefore grateful to Mr. Plymen and Mr. Prevett for presenting their paper to the Faculty—and you have shown this already in the reception you have given following their summing up of the discussion. I thank the authors and I ask you also to join with me in demonstrating your thanks to them.

The authors subsequently wrote as follows:—

1. Several speakers commented on the rather low value of the coefficient attached to the management rating in the regression analysis for investment trusts. Mr. Derby mentioned a coefficient of around 4 using a linear regression between his firm's 3-year management rating and the discount. In the analysis carried out by the authors, the coefficient obtained using the management rating as the only independent variable was 2.53. The disparity might be due to sample differences and to small differences in methods of obtaining management ratings, and also possibly in the timing
of the analysis; Mr. Derby observed his coefficient varied between 4.75 and 1.5 over a two-year period.

2. Mr. Marshall said that the authors did not explain how the investment trust assets had been calculated and that there was an implication that prior charges had been deducted at par. Assets are calculated by starting with the most recently published data and then re-calculating equity assets daily on the basis of the movements of various share price indices in relation to the proportion of equity held in each index category. The prior charges are deducted at the value shown in the most recently published data. As soon as new valuation data is published our own base valuation is brought into line; the average discrepancy between the calculated value and the published value is less than 2%.

3. Mr. Simpson made some interesting comments on the practical application of the investment trust share selection model, pointing out that investment managers should never be asked to forfeit their own judgment. The authors subscribe entirely to this point of view and maintain that models of this type should be used only as aids to decision making.

4. Mr. Murray pointed out that at the present time much research was being undertaken in industry into highly complex computer simulation models of operational activities, of which the TV Rental and Gold Mine models were relatively simple examples. The authors feel that the construction of very expensive and complex models, tailored to the needs of a specific company, can provide very valuable assistance to company management, but are not in general suited to the needs of investment managers. The authors believe that in the investment field the most useful models will generally be those which simulate the more important aspects of whole classes of industry. A development of such models, although not mentioned in the paper but nevertheless being used by the authors, is the employment of probabilistic forecasting. This involves fixing for each input variable maximum and minimum values such that the value of the variable would have less than say a 5% chance of lying outside these values. The computer then calculates results (such as earnings per share) on a similar basis, that is, with probable maximum and minimum values.

5. Mr. Dobbie referred to the gold mining model and the problem of dealing with unexpected difficulties, such as flooding, when making a valuation. To some extent such uncertainties can be accommodated by using a probabilistic model, although if the range of values for each input variable is made too wide, the resulting output will not be very helpful. One should also bear in mind that if some disaster such as flooding is almost entirely unexpected, it should not be taken into account in a valuation model until it happens!