Theshold rates of return on new mining projects as indicated by market investment results

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SYNOPSIS

Rates of return realized on investments in the gold mines of the newer goldfields outside the Witwatersrand were calculated and analysed over various time intervals and on various bases. It is shown that these rates of return are strongly correlated with changes in the gold price and cannot be equated with the returns that are expected when investments are made, and that the changes in gold price also affect the rates of return on the Johannesburg Stock Exchange as a whole. These correlations are used, together with a limited application of the Capital Asset Pricing Model, to suggest the expected levels of threshold returns in real terms for new mining projects, for projects on existing mines, and for share valuations.

SAMEVATTING

Berekenings en analises van opbrengskoerse op beleggings in die goudmyne van die nuwe goudvelde buite die Witwatersrand is gedoen vir 'n verskeidenheid van tydintervalle en basisse. Die sterk korrelasies tussen opbrengskoerse en veranderings in die goudprys word gedemonstreer; ook dat koerse wat behaal word nie aanvaar kan word as die ekwalente van koerse wat tydens beleggings verwag word nie, en dat hierdie goudprys-veranderings ook die opbrengskoerse op die Johannesburgse Aandelemark as geheel affekteer. Hierdie korrelasies word gebruik tesame met 'n beperkte toepassing van die Kapitaalbate Prysmodel teorie om die verwagte vlakke van drumpel-koerse in rieële terme vir nuwe mynprojekte, en ook vir projekte op bestaande myne en vir aandeelwaarderings voor te stel.

Introduction

The classical study by Frankel[1] of returns realized on investments in the South African gold-mining industry appeared in 1967, and covered all gold mines from 1887 to 1965. Internal rates of return (I.R.R. or D.C.F.) were calculated in current and real terms on various bases. The objective of this paper is not to update Frankel's figures in detail. Only mines from the newer goldfields are considered here (Evander, West Wits, Klerksdorp, and O.F.S.). In this group Venterspost is the oldest mine, and was first quoted on the Johannesburg Stock Exchange (J.S.E.) in 1934. Furthermore, the main effort has been directed towards a critical look at the real meaning of the returns realized, particularly as a guide to realistic threshold returns for new mining propositions, and to realistic discount rates for alternative projects on producing mines and for share valuations. Also, an attempt is made to link the results with the Capital Asset Pricing Model[2,3,4] (CAPM), which is now being applied more generally in investment analysis and is advocated for gold-share investments by Gilbertson[3].

Effects of Inflation

For the period analysed by Frankel, inflation was not very significant. In recent times, however, inflation rates have changed drastically – from a level of 2,6 per cent p.a. in the 1960s to over 10 per cent p.a. in the 1970s. Under these unstable conditions, it is contended that returns calculated and analysed in current terms have little practical meaning, and returns in real terms should be accepted as the correct criterion. Although returns have also been calculated in current (money) terms, all the returns recorded and discussed in this paper are D.C.F. rates in *real terms*. Similarly, where rates of change in factors with a monetary base have been used, e.g. changes in the gold price and in working costs, these have been converted to real terms on the basis of the C.P.I. index.

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Other Significant Factors

Details of the data sources used and the bases for the calculation of the D.C.F. returns are recorded at the end of the paper.

These historical data can be used to provide a record of returns that could have been realized by investors on the J.S.E. over various time intervals for individual mines or for a combination of gold mines, e.g. by a portfolio of all the gold shares analysed. However, such actually *realizable* returns cannot be equated with the returns actually *expected* by investors on the J.S.E., i.e. to the basic criterion applicable to new investments (see also Campbell[4]). The two measures would be comparable only if such investors were able to predict the actual changes in various critical factors that subsequently occur over the relevant time interval. Such factors are both internal and external to the mine (or portfolio) and would change between the times of purchase and sale of the shares. To the extent that such predictions prove to be optimistic or pessimistic, the returns realized will be lower or higher respectively than the returns expected at the time of purchase.

Therefore, it is essential to examine all the internal and external factors that could affect the returns, and to test the efficiency of the investors in predicting changes in these factors. Although Frankel[1] discussed some of these factors (mainly external), he did not attempt to analyse their effects statistically.

A suggested test is to correlate the returns realized with actual changes in these factors for the corresponding time intervals. If the correlation is not significant, the predictive efficiency of the investors could be accepted as good; if significant, as poor.

The most obvious factors influencing returns (in real terms) on gold-mining investments are as follows:

Internal: changes in grade, scale of operations, and working costs

External: changes in gold price, interest rates, economic growth rate, and taxation levels.

In the use of the Capital Asset Pricing Model (CAPM), the average level of return on the stock market as a whole – as based on changes in the All Shares Index and on its dividend yields – can be added as a further independent variable.

Such an approach therefore calls for gold-mine returns over specified periods (say, monthly, annually, and three-yearly) to be analysed as the dependent variable in a multiple correlation analysis against changes in the above factors for the corresponding periods. As the objective is to find suitable long-term criteria for new mining investments and for projects on producing mines, monthly periods are too short, and annual periods probably form the lower limit for the time intervals to be considered. For the sake of comparison, a few analyses of monthly periods have been included. A problem with the longer intervals is the limited number of these on a non-overlapping basis. Where they do overlap, the data can be more extensive but will be correlated via common dividend data used over the overlapping periods. The main analyses were performed for the period 1960/79, for which reasonably adequate data were available, and more limited analyses were made of the sparser pre-1960 data. In addition, some of Frankel's data were re-analysed.

Where necessary, the frequency distributions had to be 'normalized' by the use of appropriate transformations. So that the normal multiple regression model could be used in a meaningful way, all the returns were transformed logarithmically as follows:

Transformed variable $= \log_e (1 + i/100)$, where i is the untransformed rate of return in per cent per annum.

Fig. 1 shows the histogram for the 235 rates of return (for monthly periods) based on the J.S.E. All Gold Index for 1960/79, and the corresponding normal and lognormal distribution curves. The justification for the above transformation is obvious. The need for log transformations, particularly in the gold sector, has been discussed by Campbell[4].

Other variables were not transformed; some of these were also non-normal but closer to normal than lognormal.

The Use of Rates of Return

Frankel[5] reported straight averages of the rates of return calculated for successive annual periods and for successive partially overlapping periods of up to 15 years each. For the period 1935/63, for example, he averaged the returns for 19 ten-year intervals for all the gold mines at 0,2 per cent p.a. in real terms. This procedure gives maximum weight to the central ten-year interval between 1944 and 1954 (with a return well below average) and progressively less weight to the years before 1944 and after 1954; therefore, the figure of 0,2 per cent p.a. is negatively biased. This procedure can introduce serious biases in the average return for the period, particularly if the time intervals are long.

Even where the overlapping of time intervals is not serious, a further problem arises from the use of a straight average of the successive returns. This will be evident from the following example, which is based on the monthly returns realized on the basis of the J.S.E. All Gold Index over the period 1960/79:

	% p.a.
(*a*) straight average of 235 real D.C.F. returns for monthly periods (including one return of over 8000 per cent p.a.)	101
(*b*) real D.C.F. return calculated from a single set of cash flows over the full period 1960/79	9,2
(*c*) Return corresponding to geometric mean of 235 monthly $(1+i/100)$ figures	8,0

Theoretically (b) and (c) should be the same, and should correspond to the position at which a capital amount is effectively invested in shares at the beginning of the period and the shares are sold at the end of the period. Case (a) will apply where the investor sells his shares at

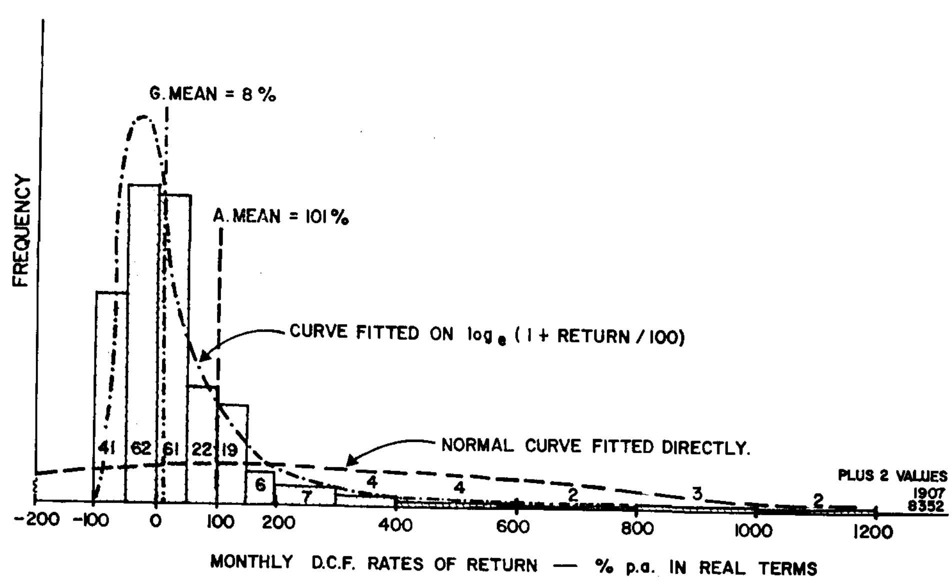

Fig. 1—Distribution of 235 monthly rates of return on the All Gold Index for 1960/1979 in real terms

the end of the first month and re-invests an amount similar to his original capital in the shares for the next month, and repeats this process from month to month, i.e. the investor pockets any capital gains and makes up any capital losses at monthly intervals. Frankel[1] called (b) and (c) the *lump sum* method and (a) the *periodic investment of constant money sum* method. Except for short-term speculative transactions, the correct method appears to be (b) and (c), and not (a). In this paper, the former are referred to as the *mean return over the period* and the latter as the *mean of the interval returns.*

Preflotation Expenditure

Apart from analysing the returns on investments made on the stock exchange, Frankel also attempted to quantify the actual returns realized by the original vendors who acquired the prospecting rights, financed the exploratory activities, floated the mining company, and, following their contributions to the company's capital requirements, reaped their returns via dividends and the eventual sale of their shareholdings. On floating their companies, they could have received cash refunds of their exploration and other ancillary expenditures (where these are usually re-invested simultaneously in shares at par), plus an additional 'net vendors' consideration handled in the same way. Frankel encountered serious problems, which still exist, in obtaining complete data on the amounts and timing of exploration expenditures relevant to particular mines.

In the present exercise, this approach was abandoned because of these data problems and also because the returns that could be obtained even with realistic data would still reflect the *actual returns* realized by the vendors, and not the *threshold returns* required to justify the flotations.

Where a new mining project is to be floated on the market, an estimate of the threshold for the flotation can be accepted as equivalent to the rate of return expected by the market on the first market prices for the shares. If the share commands an immediate premium, the market investor would expect to realize the threshold return on the par plus premium value, and the original vendors could obtain a higher return. The actual return to the vendors will be boosted further by any net vendors' consideration, for which shares were obtained at par, but would be watered down if actual exploration expenditures (incurred in most cases over many years) are refunded exclusive of any realistic interest return on them.

If the market price just after flotation corresponds to at least par, it seems a valid conclusion that the total capital required for the mine and for compensation of the vendors could have been raised from the public at par and, therefore, that the mine was just viable. The market rate of return on such shares at that time should then also approach the minimum return expected by the vendors themselves on their own cash outlays for exploration, etc., incurred in the discovery and flotation of the mine.

In the estimation of the threshold returns on this basis, the limited number of mines and the varying external factors at their individual dates of flotation present a serious problem. Therefore, in the data analysed, the returns indicated have been divided into two main categories only: preproduction plus the first three years of production, representing in most cases some eight annual intervals covering the more risky stage for a new mine; and the subsequent period of more or less settled production and lower risk levels. The former category has been divided further into the preproduction and early production stages for an analysis based on more limited data, where the preproduction stage should approach the conditions at flotation.

Marketing Efficiency in Anticipating Changes

Multiple regression analyses were done on the data collected for the mines in the newer goldfields (details at the end of the paper) for the period 1960/79 on the following bases:

Individual mines: annual and three-yearly intervals.

Means of mine returns for the same annual periods (equivalent to annual returns on an index of the new gold mines).

In addition, analyses were done based on the J.S.E. All Gold and All Shares Indexes on monthly, annual, and three-yearly intervals. Similarly, Frankel's published returns for all gold mines combined on an annual basis for 1935/63 were correlated with corresponding changes in the gold price, data for all the other factors not being readily available. For the same reason, the data collected for the pre-1960 period, as shown at the end of the paper, were analysed without correlations with any of the other factors. In all relevant cases, the returns over the full periods were calculated, but, because of data limitations, these could not be correlated with changes in the internal and external factors.

These analyses show that all the returns on gold indexes, as well as virtually all the returns for individual mines, are correlated very significantly with changes in the gold price; correlation coefficients were concentrated heavily in the range 0,6 to 0,7. An example of these correlations is given in Fig. 2 for returns on the All Gold Index (1960/79) over three-year periods. Only in isolated cases did significant correlations, but at a low level, arise with one or two of the factors of working cost, tonnage milled, government stock rates, and grade changes. Therefore, the conclusion to be drawn is that the J.S.E. is generally a poor predictor of changes in the gold price, but is reasonably efficient in anticipating changes in the other factors considered.

Therefore, changes in the gold price were accepted as the main outside factor, and Table I records, apart from the returns measured directly, the regressed returns based on correlations with changes in the gold price. These latter returns, in the last column of Table I, represent the regressed estimates of the real D.C.F. returns corresponding to an expected zero change in gold price. Transformations to log $(1+i/100)$ were used for returns, and the regressed estimate was obtained by solving for i directly from the transformed regression estimate. The normal correction for the regression line to agree with the means of the untransformed conditional distributions (see Krige[6]) was not effected, since the objective was the estimation of the geometric mean, and

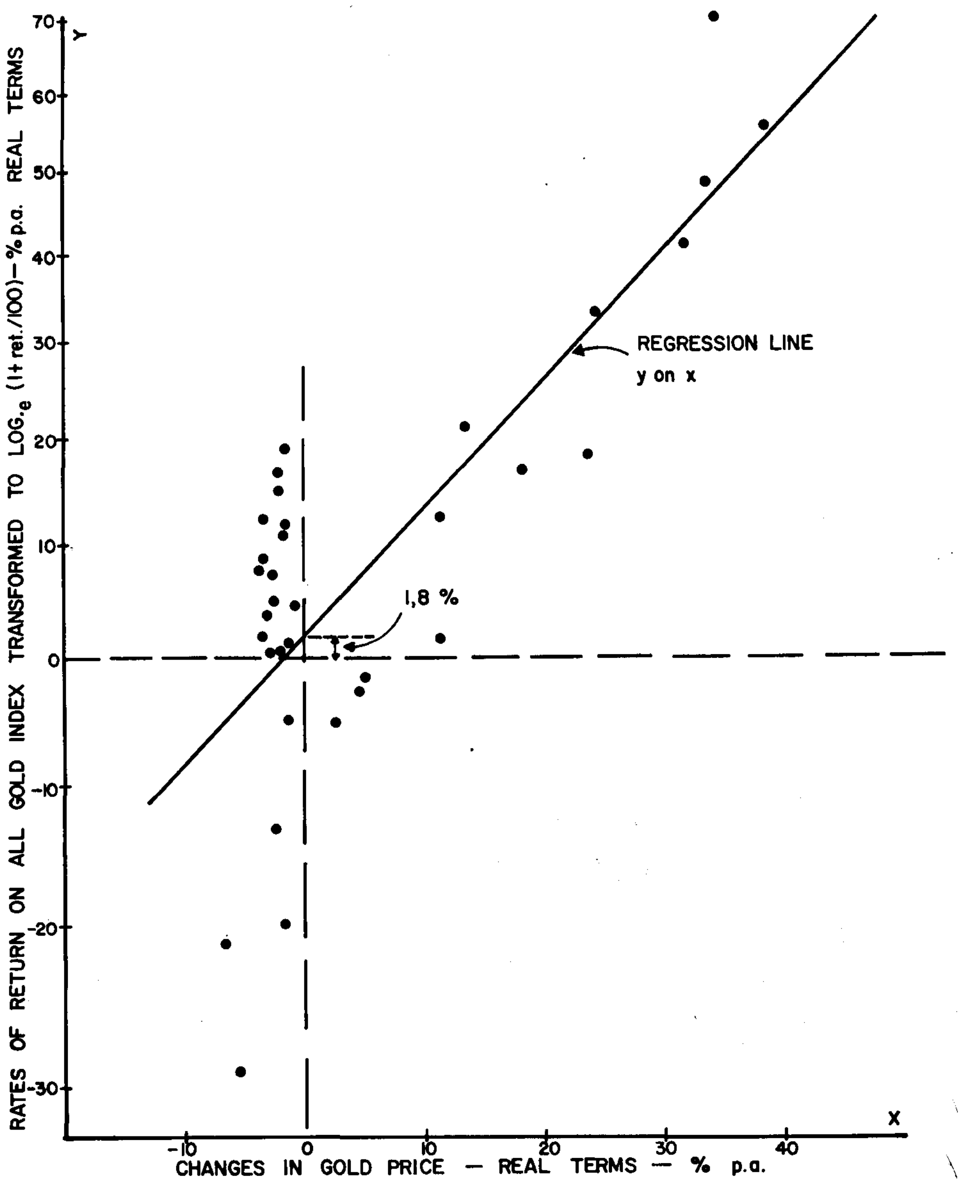

Fig. 2—Regression of rates of return on the All Gold Index for three-year periods in 1960/1979 against the corresponding changes in the gold price (all in real terms)

not the arithmetic mean. Therefore, the returns in the last column of Table I provide a first indication of the levels of return expected as a *threshold* for new mines (category 1) and for new projects on producing mines (category 2).

It could be argued that the J.S.E. was not expecting a zero change in the real gold price in the period 1960/79, but on balance some positive long-term rate of increase that would obviously raise the estimates shown in the last column. However, the estimates for 1960/79 (corresponding to a zero change in gold price) range generally from $1\frac{1}{2}$ to $3\frac{1}{2}$ per cent, and agree very well with the corresponding 2,7 per cent for 1935/63 based on Frankel's data. In this latter period there was a long-term but very small negative annual change in the real gold price, and the regressed estimate for a zero change (2,7 per cent) differs only slightly from the direct unregressed estimate for the period (2,0 per cent). This seems to support the contention that the J.S.E. investors in gold shares do not on balance anticipate persistent long-term changes in the gold price in real terms. It also seems to indicate that the returns expected for the same long-term view of the gold price are not necessarily higher (as would be expected from the CAPM) during stages when the gold price is more volatile (such as was the case during the last decade).

Further research on more detailed information showing the efficiency of the J.S.E. in anticipating changes in the other factors could be warranted, as well as the possibility of time lags being operative for the maximum effects of some of these factors.

Table I also shows the returns on the J.S.E. All Shares Index over various time intervals for the period 1960/79. These returns were also correlated with changes in gold price, and the correlation coefficients were as follows: 0,34 for monthly periods, 0,30 for annual

TABLE I

D.C.F. RATES OF RETURNS IN REAL TERMS (IN PERCENTAGES PER ANNUM)

Period	Interval for return	All shares – J.S.E. Index			Gold shares				
		Mean interval return	Mean period return	Mean period return – constant gold price	General category	Risk* category	Mean interval return	Mean period return	Mean period return – constant gold price
Frankel's data re-analysed (Appendix C, Table 7 and Appendix B, Table 2)[1]									
1935/63	Annual	—	—	—	All mines	1+2	3,2	2,0	2,7
1935/63	Full period	—	—	—	All mines	1+2	—	1,4	—
Data from sources given in this paper									
1934/59	Annual	—	—	—	Annual averages all mines in	1	9,0	3,0†	—
1934/59	Annual	—	—	—	new fields	2	3,5	1,0†	—
1960/79	Monthly	35,3§	7,4	4,2	J.S.E.	1+2	101,4§	8,0	2,7
,,	Annual	11,5	8,5	5,5	All	1+2	15,0	9,4	1,3
,,	3-yearly	7,6	6,6	5,8	Gold	1+2	10,2	8,4	1,6
,,	Full period	9,6	9,6	—	Index	1+2	9,2	9,2	—
,,	Annual	—	—	—	Annual averages	1	18,8	12,1	3,5
,,	Annual	—	—	—	for all mines	2	17,9	11,5	1,4
,,	Annual	—	—	—	in new fields	1+2	18,5	11,4	1,4
,,	Annual	—	—	—	Period returns for 20 mines in new fields	1+2	9,8	9,8	0,1‡

* 1 = preproduction plus first 3 years production; 2 = thereafter.
† These correspond to an average annual decrease in the real gold price of 1 per cent over the period 1935/59, and the coresoonding figures in the last column should therefore be somewhat higher.
§ Includes some obvious outlier values – mean value misleading.
‡ See Table II for details.

periods, and 0,12 for three-yearly periods. The monthly correlation is highly significant, and the annual figure is marginally significant. Significant correlations were observed with the independent variables of Government Stock rates and economic growth rate. Column 5 in Table I reflects the indicated regressed estimates for the All Shares returns corresponding to an expected zero change in gold price.

Table II gives more details of the individual results for the 20 gold mines corresponding to the mean figure of 0,1 per cent in the last line of Table I.

Table III provides further details of the effects of changes in the gold price on individual mines and groups of mines, and is discussed later.

Capital Asset Pricing Model[2, 3]

This theory suggests that, when the market returns for a particular share are correlated as the dependent variable with the returns achievable on the market as a whole for corresponding time intervals, the slope of the regression line—called the *beta* (β) *factor*—provides a direct measure of the systematic market risk associated with an investment in that share.

TABLE II

DISTRIBUTION OF REGRESSED RETURNS (CORRESPONDING TO A ZERO CHANGE IN GOLD PRICE) FOR 20 MINES IN THE NEWER GOLDFIELDS.

Return limits % p.a.	No. of mines	
	6	
0		
	4	Mean = 0,1 % p.a.
1		
	2	
2		
	4	
3		
	2	
4		
	2	
5		
Total	20	

Note: Only mines with complete data for the period 1960/79 were included.

Furthermore, the return that the market will expect from a share can be expressed in the form

$$R_j = R_F + \beta(R_M - R_F),$$

where R_j = expected rate of return on the particular share,

R_F = rate of return on risk-free investments,

β = regression slope as defined above, and

R_M = expected rate of return on the whole market portfolio of risky assets.

Theoretically, in applying this model the analyst should be able to estimate R_F from the regression of market returns for individual shares on their corresponding β factors. R_F would then be measured by the return corresponding to a β factor of zero; also, the correlation between the returns and β factors should be positive.

The application of this theory to the returns on individual mines and on the indexes for monthly, annual, and three-yearly intervals over the period 1960/79 met with only partial success. As for the basic analyses, the returns were all used on a transformed basis and were all in real terms. The β factors obtained are listed in Table IV on two bases:

(1) on a direct regression of the returns on the All Shares Index returns, and

(2) on a multiple regression with changes in the gold price as an additional independent variable.

From some parallel regression analyses done on an untransformed basis, it appears that transformation does not affect the β factors to any serious extent (see also Campbell[4]). However, as discussed earlier, the average returns obtained will be very seriously and positively biased as they would correspond to *means* and not to *geometric means*.

From Table IV it is evident that average β factors of about 0,8 and 0,6 appear to apply to gold mines over the period 1960/79 (ignoring changes in the gold price and correcting for such changes respectively). Also if the risk-free rate for this period is accepted at 1,5 per cent p.a. (i.e., the average real-term rate on long-term government stocks), the corresponding expected rates of return on gold mines should be 6,3 per cent and 3,6 per cent respectively from the above formula (see Table IV). It is contended that the effect of changes in the gold price cannot be ignored and that, if it is accepted that the J.S.E. does not anticipate such changes and that the CAPM applies, the latter figure should be preferred as a more realistic estimate of the *threshold* rate of return for new projects on producing mines.

The estimation of the risk-free rate by correlation of the regressed returns for the 20 mines (Table I, last line) with their corresponding β factors (Table IV) failed because of a significant negative correlation. However, the CAPM approach used did not take account of factors such as changes in the β factors during the time period, and the results are not presented with much confidence.

A further approach that might prove worth while is an analysis of the extent to which the β factors for individual mines for the period immediately following flotation are on balance higher than at the later stage of steady production. However, such analyses would have to be done on short time intervals of weeks or months, with confirmatory evidence that the β factors obtained will also apply to longer-term investments.

TABLE III

REGRESSION OF ANNUAL RETURNS (TRANSFORMED) ON CHANGES IN THE GOLD PRICE

Gold Price Regression Coefficients

Individual mines	Coef. limits	No. of mines	
		1	
	0.00		
		2	
	0,005		
		7	
	0,010		
		13	Mean = 0,012
	0,015		
		5	
	0,020		
		2	
	0,025		
	Total	= 30	

	Coefficients
Monthly–All Gold Index	0,0922 (monthly % changes in gold price)
Annual —All Gold Index ..	0,0105
Annual averages for mines in newer goldfields:	
Category 1	0,0109
Category 2	0,0130
3-year periods—All Gold Index ..	0,0108

Discussion of Rates of Return

From Table I (last column) and the previous section, it is concluded that, when no maintained change in the gold price (in real terms) is foreseen, the J.S.E. expects

TABLE IV

REGRESSION OF GOLD MINE RETURNS ON ALL SHARES RETURNS

Regression coefficients (β factors) — period 1960/79

	Direct regression			Regression with change in gold price as additional independent variable	
Individual mines (annual periods)	β category Limits	No. of mines		No. of mines	
		1		1	
	0				
		0		0	
	0,2				
		1		3	
	0,4				
		3		6	Mean = 0,62
	0,6				
		6		12	
	0,8				
		10	Mean = 0,84	7	
	1,0				
		6			
	1,2				
		3			
	1,4			—	
	Total	30		Total 29	
		β Values		β Values	
Monthly — All Gold Index		1,00		0,92	
Annual — All Gold Index		0,81		0,62	
Annual averages for new mines					
Category 1:		0,72		0,52	
Category 2:		0,90		0,65	
3-yearly periods — All Gold Index		0,74		0,63	
Estimate of gold mine return based on CAPM (safe rate = 1,5%)		1,5+0,8 (7,5*−1,5) = 6,3% p.a.		1,5+0,6(5*−1,5) = 3,6% p.a.	

* From Table I, columns 4 and 5.

on average *a real return of, say, 3 per cent p.a. on producing gold mines*. This appears anomalous in relation to the corresponding return of about 5 per cent p.a. expected on the J.S.E. as a whole (column 5, Table I), but the differential agrees with the observed β factors of less than unity for the period 1960/79. This return of 3 per cent p.a., if corrected for the current inflation rate of 14 per cent p.a., corresponds to a current-terms rate of return of about $17\frac{1}{2}$ per cent p.a., which is still well below the returns of up to 30 per cent p.a. suggested by Gilbertson[3]. The main reason for the differences could be as follows: Gilbertson did not adjust his returns or factors to correspond to expected zero changes in gold price, he effectively used means and not geometric means, he did not use transformations or real-terms returns, and his analyses are based on and aimed at relatively short-term investment intervals.

Therefore, it is suggested that new projects on producing mines should be evaluated at *an average discount rate in real terms of 3 per cent p.a.*, corresponding in current terms for an average future inflation rate of say 9 per cent p.a. to *a discount rate in current terms of* $12\frac{1}{4}$ *per cent p.a.*,

i.e. $[(1+3/100)(1+9/100)-1]100$.

These rates should be applicable also for share valuations. These are long-term average rates that could, and probably do, vary significantly over shorter time periods. To the extent that the CAPM approach proves applicable and reliable recent factors can be determined, corresponding differential rates of return could be used for individual mines. However, if the objective is a criterion for long-term investments, it is difficult to see how adequate data can be obtained from a data period much shorter than that used in this investigation (1960/79).

From Table I, the differential between the results for category 2 (or 1+2) on the one hand and category 1 on the other hand appear to be about 2 per cent p.a., corresponding to an average rate of return for category 1 of say 5 per cent p.a. in real terms. This is still too low as a threshold return for new mines since it refers to the full preproduction period and the first three years of production. On the limited data available for preproduction periods during 1960/79, it appears that, for the above average figure of 5 per cent, the corresponding figure for the preproduction period could be some 6 to 7 per cent p.a. and (by extrapolation) say 7 to 8 per cent p.a. at flotation. As the CAPM cannot be applied before a market record exists, it cannot be used to suggest variations from this average rate for individual projects, and, therefore, a risk analysis approach[7] is indicated.

Net Effect of Changes in the Gold Price

The average slope of the line for the regression of returns on changes in the gold price (Table III) indicates that a 25 per cent increase in the real gold price over a period of a year should raise the factor $(1+i/100)$ by some 33 per cent for that year; that is, a 3 per cent D.C.F. return in real terms would improve to 37,3 per cent and correspond to a share price increase of some 34 per cent in real terms. If the gold price then steadied and the annual returns reverted to 3 per cent p.a. over the remaining mine life of, say, 19 years, the average real return over 20 years would have improved from 3 to 4,5 per cent p.a. An independent check, performed to quantify this effect via detailed life cash-flow estimates for a sample of five mines from the new goldfields, shows a corresponding increase from a return of 3 per cent to one of 5,8 per cent p.a. Of course, the effect on individual mines will be influenced significantly by the extent, if any, to which the grade will be reduced as the gold price increases.

It is also clear from this analysis that, if it could be shown that the J.S.E. in valuing gold shares is not expecting a zero change in gold price (real) but, say, a 2 per cent p.a. increase to be maintained indefinitely in real terms, the threshold returns of 3 per cent and 7 to 8 per cent p.a. will be raised to about $7\frac{1}{2}$ per cent and $9\frac{1}{2}$ to $10\frac{1}{2}$ per cent respectively. It is, however, difficult to see any justification for such an assumption.

Conclusion

The indicated order of the average threshold return for new mines is some 7 to 8 per cent p.a. in real terms, and the corresponding average discount rate for producing mines some 3 per cent p.a. (real). These correspond to expectations of no long-term maintained change in the gold price in real terms. Changes in the gold-price level (real terms) will have significant effects on the returns actually achieved.

Data Sources

Gold Prices: Quarterly from 1934 taken from the *Chamber of Mines Quarterly* and *Annual Reports*. Class B mines (uranium producers) were omitted. Monthly figures were based on London prices in dollars per ounce taken from *Metals Week* and were converted to Rands per kilogram according to exchange rates obtained from *Reserve Bank Bulletins*.

Working Costs: Quarterly from 1934 from the *Chamber of Mines Quarterly* and *Annual Reports*. Class B mines were omitted.

South African Consumer Price Index: Monthly from July 1934. Supplied by the Department of Statistics, Pretoria.

Equity Issues: Details were taken from prospectuses and annual reports. Allowances were made for shares issued to non-shareholders.

Mine dividends: These were taken from annual reports and the *Johannesburg Stock Exchange Monthly Bulletin*.

Share Prices: Up to and including 1971 the figures came from data compiled by the Chamber of Mines for use in the book by S. H. Frankel[1]; average figures for March and October were used. From 1972 to 1979 the figures came from the *Johannesburg Stock Exchange Monthly Bulletin*, when average figures for February and August were used.

Long-term Interest Rates on Government Stock: 1960 to date were obtained from the Treasury in Pretoria.

Economic Growth Rates: Were based on GDP at constant 1970 prices as provided by the S.A. Reserve Bank from 1946 to date.

All Shares and All Gold Indexes: *J.S.E. Actuaries Index*, Second Edition.

Dividends on J.S.E. All Shares Index and All Gold Index: Yields from the J.S.E. indexes were converted to annual dividends relative to the levels of the indexes and then split on a quarterly basis across the year approximately *pro rata* to the number of companies paying dividends (All Shares Index) quarter by quarter, and the dividend payments for all gold mines (All Gold Index).

Mine Cash Flows Used for Estimates of D.C.F. Returns: Shares at start of time interval at the J.S.E. market price (negative), plus capital invested in new issues to which these shareholders are entitled during the interval (negative), plus any dividends received on these shares (positive), plus the shares held at the end of the time interval at the corresponding J.S.E. market price (positive) – all in the months in which they occurred. The monthly D.C.F. rate was calculated and converted to the equivalent annual rate by compounding monthly over 12 months.

Companies analysed: (Up to dates of mergers or take-overs where relevant).

O.F.S.: Loraine, Freddies (North, South, and Consolidated), F.S. Geduld, Harmony, Virginia, Merriespruit, F.S. Saaiplaas, W. Holdings, Pres. Brand, Pres. Steyn, St. Helena.

Klerksdorp: Western Reefs, Vaal Reefs, South Vaal, Zandpan, Hartebeestfontein, Buffelsfontein, Stilfontein.

W. Witwatersrand: Elandsrand, Deelkraal, Doornfontein, Blyvoor, West Drie, Western Deeps, East Drie, Kloof, Libanon, Venterspost, Elsburg, Western Areas.

Evander: Leslie, Bracken, Winkelhaak, Kinross.

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Chemical engineering

The 2nd World Congress of Chemical Engineering, 'Chemical Engineering For World Development', will be held in Montreal in 1981, 4th to 9th October. It will coincide with the IX Interamerican Congress of Chemical Engineering and the 31st Canadian Conference of Chemical Engineering.

The first World Congress was held in Amsterdam in 1976. The Montreal Congress, like its predecessor, will provide a unique forum for chemical engineers of all nations to exchange ideas for the benefit of mankind.

The intearmerican Confederation of Chemical Engineering, host for the 1981 Congress, has designated the Canadian Society for Chemical Engineering to be responsible for its organization.

The official languages will be English, French, and Spanish.

The technical programme will include sessions covering all the important aspects of chemical engineering. Twelve sessions will be held simultaneously. Each session will contain five to seven half-hour presentations, including discussion.

Emphasis will be placed on contributions of the highest quality and originality. Plenary addresses will be given by prominent international authorities and sessions will be keynoted by presentations from distinguished chemical engineers.

The themes are as follows:

1. *Economic and Technological Outlooks:* chemical industry outlook; technological projections; innovation.
2. *International Co-operation:* technology transfer; career planning for international practice.
3. *Management and Productivity Aspects of the Chemical Industry.*
4. *Sesiones de la Confederacion Interamericana:* alimentacion, energia, problemas ambientales (Sessions to be conducted in Spanish).
5. *Fossil Resource Development — Energy and Petrochemicals:* projected uses of oil and gas; coal; heavy oil — tar sands and shale; feedstock projections; trends in refinery process technology; environmentally acceptable fuel processing.
6. *Energy Development and Utilization:* thermal energy storage; engineering applications of solar energy; hydrogen as fuel; energy from forest and agricultural products; energy conservation in the chemical industry.
7. *Nuclear Engineering:* heavy-water production; uranium mining, milling and refining; nuclear fuel cycle — extending uranium resources and environmental impact; nuclear steam for process and resource industries.
8. *Fundamentals:* transport phenomena, thermodynamics; mathematical applications.

The World Chemical Exposition will be held concurrently with the Congress on 6th to 8th October. Over 500 exhibitors will display and demonstrate the latest products, equipment, processes, instrumentation, and services related to the chemical, petrochemical, energy, and allied industries. Over 50 countries will participate. Admission to the Exposition will be included in the Congress registration fee.

Those interested should contact Congress Secretariat, 2nd World Congress in Chemical Engineering, Canadian Society for Chemical Engineering, 151 Slater Street, Suite 906, Ottawa, Ontario, Canada K1P 5H3.