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"Evaluating Risk in Project Investment"

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This paper is concerned with appropriate procedures for evaluating risk in project analysis. Risk is defined as estimation uncertainty arising from use of forecast yields and prices. A special aspect of risk discussed here concerns investment designed to overcome natural uncertainty over yield parameters such as irrigation investment provides. At issue is whether risk should be accounted for in the discount rate or in the cash flows? If the discount method is employed, can the CAPM model provide better risk-adjusted estimates? If the project investment changes the risk environment, can the analyst provide policy makers with quantitative analysis of the effects? If the risk environment changes, who benefits? Who should use risk-adjusted rates of return?

Introduction

In both the public and private domain the normal approach to project evaluation involves some form of discounted cash flow (DCF) analysis. The result is expressed as an internal rate of return (IRR) or as a net present value (NPV). The latter involves some choice as to the discount rate, and the reasons for choosing any particular rate. Very often, analysts use single values for yield and price parameters and provide single values of the IRR or the NPV. (Such single values tend to represent the mode of an implicit distribution of each variable and hence provide some estimate of a modal result). Decision makers became accustomed to single valued result parameters and consequently assume a certainty about the estimates which is not warranted.

It is this uncertainty about the outcome of an investment that is the theme of this paper. It is assumed that an ex ante approach to an investment project is being taken and that the decision maker wishes to know something about the range of results that could arise from valid assumptions about forecast

* This paper has benefited from an earlier paper and discussions with Rod Forbes and Peter Seed.

values of prices and quantities. In effect risk is being defined as a probability of reaching or not reaching a certain result arising from uncertainties about forecasted data.

The method of doing this is to estimate probability distributions for all input variables and use a modern software package to generate all possible values of the IRR and NPV. These packages provide normal and cumulative distributions of both the IRR and the NPV.

I is then possible to start the education of decision makers on estimation uncertainty. Particularly important are comparisions of different projects as well as relatively large ranges of results within projects. The latter can indicate poor data standards and forecasting techniques, but also a wide range of underlying uncertainty.

Some analysts incorporate a form of sensitivity analysis to overcome the problems described above. The problem with arbitrary selection of sensitivity values for input parameters is that they have no probabilistic basis. Hence the result parameters using sensitivity values are also arbitrary.

A particular problem with the use of probability distributions of input data is that the investment under evaluation may itself alter the risk parameters surrounding a project. A good example is an irrigation investment where agricultural yields are likely to be less variable in the with project situation compared with the without situation. Single value estimates do not pick up such changes in risk status and financing arrangements typically ignore who the beneficiaries are from the reduced risk status.

In this paper we discuss concepts of risk in more detail, discuss the theoretical and practical application of probability distributions to the estimation of the IRR and the NPV, analyse alternative approaches to the discount rate assumption including the use of the capital asset pricing model (CAPM), and discuss how an option pricing model can place a value on changes in risk status.

Risk Concepts

Risk and uncertainty have separately defined meanings; risk referring to statistically measurable variation and uncertainty referring to the non-measurable. For this purpose, the meanings are combined in a definition of all uncertainty associated with future events affecting some investment project. As indicated above, the approach taken is to recognise the inherent variabilty in all data inputs used in an analysis and to use variance-covariance models to produce appropriate data outputs or results. We use the term estimation uncertainty to convey this approach.

There are certain parallels with portfolio analysis in this approach. A group of variables have to be combined in a single result statistic having regard to their variances and covariances. In portfolio analysis risk is minimised by appropriate selections of shares or enterprises. In budgeting and project analysis, individual variability and uncertainty of data sets is aggregated to a single risk measure associated with an output variable like the IRR or the NPV.

In planning a project the likelihood of success in reaching a desired rate of return needs to be known. The risk of not reaching that return is a matter for managers to resolve. This would involve some form of the corporate finance model which defined the corporates' required rate of return to equity in risk terms. Here risk is recognised as a safety margin based on some specified measures of variablility experienced in the past. Risk adjusted return on equity can recogire different risk situations in different investment opportunities.

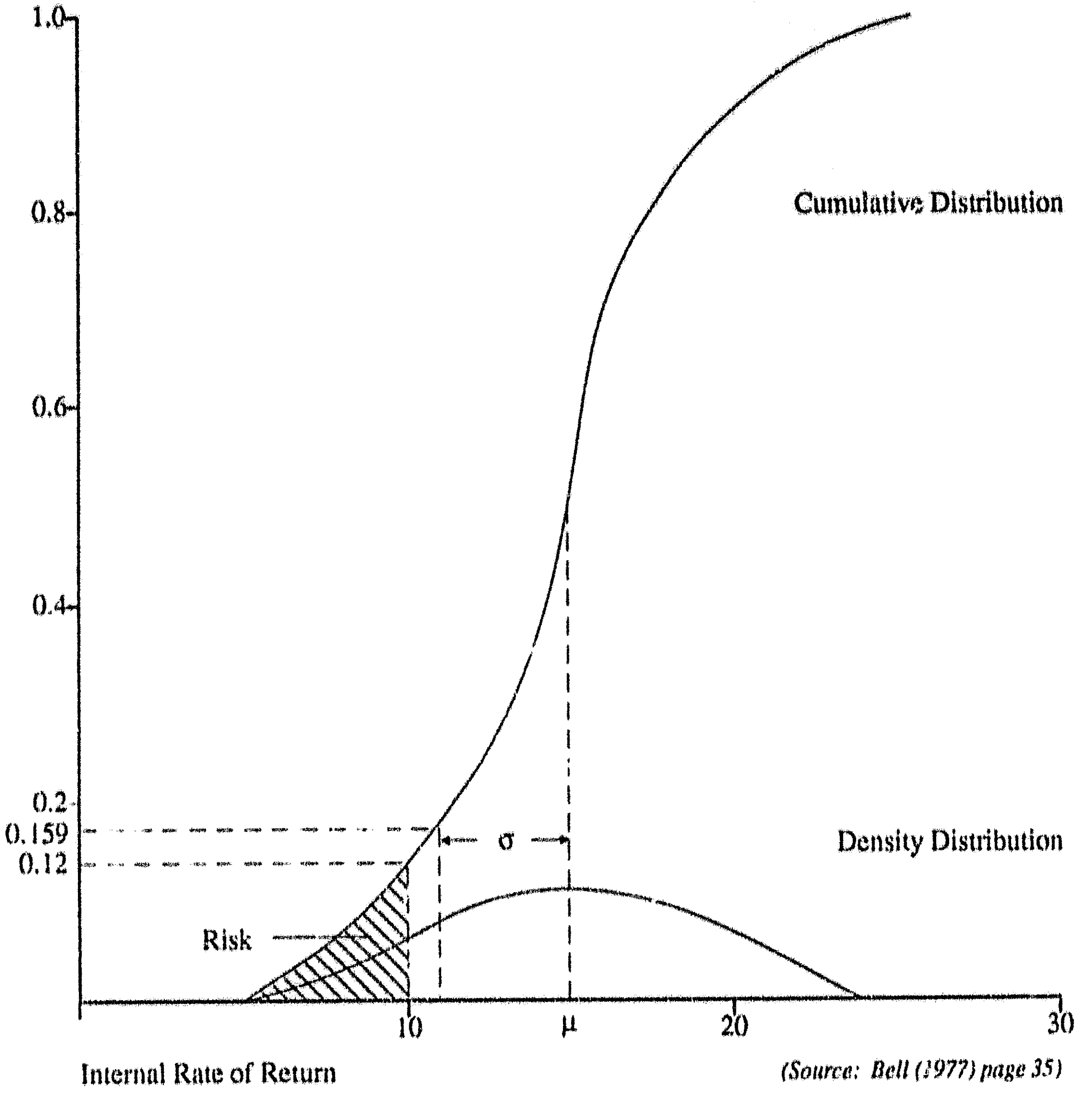
Once the risk return to equity is known, it would be quite appropriate to use that rate as a basis for the discount rate determination. Projects with lower returns would lower the corporate return on equity and projects with higher returns would raise the corporate return on equity.

The risk adjusted return on equity can also be approached through the capital asset pricing model. CAPM partitions total variation in a data set into systematic and non-systematic risk. Systematic risk is associated with uncertainty asociated with market conditions, macroeconomic trends and climatic factors. Non-systematic risk relates to within firm organisational and management responses to external pressures. CAPM isolates the systematic component of risk through the beta coefficient (B) formula. The formula can then be used to estimate the premium which should be added to a risk-free rate of interest to represent systematic risk. Such a procedure may give a different indication of the appropriate discount rate to the desired rate of return on equity described above.

To establish the possible variance of each input parameter in the variance-covariance approach, historical records are needed of past variation or, in the absence of such records, experienced analysts must make subjective estimates. The latter technique is borrowed from decision making theory. Suggested techniques include an assessment of a triangular distribution of the variable or a more complicated step rectangular distribution (Forbes 1984 p 30). The triangular distribution involves the analyst in making the best possible estimate of the lowest expected value, the highest expected value and the most likely value. Given these values a mean and a standard deviation can be calculated. For standardisation purposes and analytical honesty appropriate rules are required to define just what low and high mean in this context. One way of doing this is to specify whether a 10 year event or a 100 year event is being simulated. Old data series sometimes assist in this task, though it is the future trend which is being estimated.

To recapitulate, risk is measured as uncertain outcome in input variables. Total risk is the aggregated variance-covariance output set of results. These show appropriate distributions for

Figure1-Probability Distribution of the Internal Rate of Return



(Source: Bell (1977) page 35)

key statistics such as the IRR and NPV. Decision makers can assess uncertain results within projects and comparable uncertainties between projects. Project rankings can potentially change when such assessments are carried out.

Probability Distributions

Following the methodology indicated above, the analyst prepares a set of results showing the IRR and NPV at the expected means of their distributions and an estimate of the standard deviation about the mean. The methodology converts modal or most likely input values to expected mean values and all results are determined as expected values.

Most software now provides such results effortlessly. We are left with interpreting what it means for project analysis. Figure 1 shows the cumulative and density probability distribution for the IRR. In this example the expected IRR is 10 per cent and its standard deviation is 4 per cent. Normal distribution tables show that 0.159 of the area of the cumulative probability distribution lies on each side of one standard deviation from the mean, as in the figure, or 0.05 of the area of the distribution lies to the left of 1.96 times the standard deviation. Alternatively, it is possible to state what the probability is of obtaining a certain value of the IRR. In this case, there is a 0.12 probability of obtaining an IRR of less than 10 per cent. Another alternative is to estimate the percentage probability of an NPV greater than xero. In the diagram, this happens to be 0.87.

The interpretation of the probability distributions of the result statistics can be judged from Figure 2. Within a project, tight estimates of the input parameters should produce cumulative and density distributions the shape of A. Uncertainty about the base data could produce a result as in B. The quality of the work in A is likely to be higher in A than B.

Alternatively, the decision maker might examine A and B as two comparable projects with the same expected IRR. In this case the standard deviation will be smaller for A and the net present worth will have a greater percentage probability of being greater than zero.

Table 1 shows some results estimated for a case study of an irrigation scheme (Seed, Forbes and Johnson 1992). In this case, an existing scheme is being valued for privatisation. The without situation is the farming pattern if water is withdrawn, and the with situation is continued supply of water. In effect the model attempts to measure the annual value of water. The following input variables were expressed in stochastic terms: price of wool, price of lamb, price of milkfat, wool per stock unit and lambs per hectare. Other variables are held at their expected means. Investigation showed that the variability of net returns for dryland sheep farming was twice that of irrigated sheep farming, and irrigated wheat production reduced variability by more thn twice that of dryland (Sriramaratnam and Arthur-Worsop 1990). The results show the value of water if the scheme is

Figure 2: Comparison of Internal Return of Two Projects

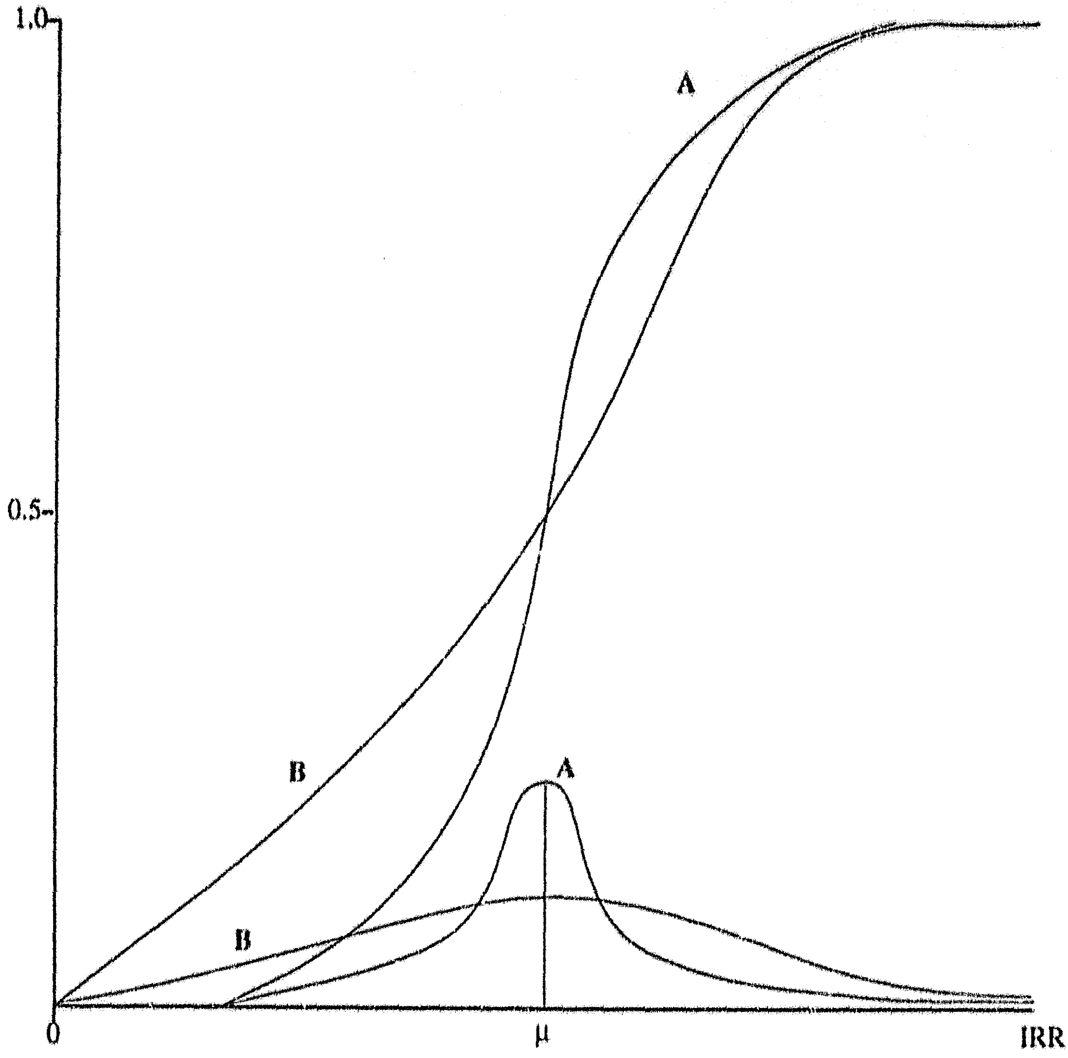


Table 1 Valuation of irrigation assets using ANWA		
Discount rates	10%	12%
All land uses	($ million)	
Net present value	15.58	12.79
Standard deviation	1.28	1.17
95 percentile		
• from	13.07	10.50
• to	18.10	15.08
Coefficient of variation	0.08	0.09
Sheep land use		
Net present value	9.72	8.00
Standard deviation	1.68	1.52
95 percentiles		
• from	6.43	5.01
• to	13.01	10.99
Coefficient variation	0.17	0.19

Table 2 Estimates of annual "drought insurance" premiums per $1,000 of annual gross revenue

	Pastoral	Arable
Irrigated	7.92	44.27
Dryland	37.53	72.18
Irrigated/dryland differential	29.61	27.91

Table 3 Estimates of the total annual value of risk reduction for the Morven-Glenavy irrigation scheme (1988 dollars)

Land use	Area ha	Dryland gross revenue $/ha	"Premium" differential % of gross revenue	Value of risk reduction $
Sheep	4,650	195.28	2.961	26,887
Beef	150	198.67	2.961	882
Deer	300	854.64	2.961	7,592
Dairy	1,550	733.83	2.961	33,679
Crop	1,200	945.00	2.791	31,650
TOTAL	7,850	-	-	100,690

Notes: *The premium differential is the difference between the irrigated and dryland notional premiums in $ per $1,000 of gross revenue. The value of the risk reduction is the product of the area of land use, the gross revenue and the percentage premium differential.*

devoted to mixed farming as compared with using the resource entirely for sheep production.

Broadly speaking, the mixed farming scenario is more profitable than sheep production and is also less variable. The variance and covariance data used in the calculation provides the latter conclusion as expressed in the coefficient of variation for each farm scenario. This is also shown in the 95 percentile limits for each scenario where the absolute and the percentage range of the NPV are both greater in sheep production. The basic reason lying behind this result is that lamb production under dryland conditions is more variable than any other enterprise.

These results illustrate the scope of the model presented and which could be applied to many other related investment analyses. There is a need for uniformity in estimating the stochastic input variables to be consistent across projects. Uniform sets of covariances are also useful (Forbes 1990). The principles apply to a single years forecast budget as much as a DCF analysis (Forbes 1992).

Estimation uncertainty is adequately described and modeled. Changes in uncertainty can be easily incorporated. Comparisions can be made within projects and between projects. The quality of decision making is improved.

The Discount Rate

Thus far we have taken the discount rate for granted. It is necessary to distinguish between public and private investment. Public investment is concerned with the opportunity cost of national resources and is relatively risk free. This suggests a discount rate set at long term borrowing rates on funds used by Government with a small risk margin. The essence is to be able to get the social cost of capital and the social return correctly estimated. For an exception to this see the discussion of capital charges for contestable government services below.

Private investment should be governed by the corporates' required return on equity after tax. Anything less lowers the gross return on corporate equity and anything more improves it. The required return on equity is made up from the standard borrowing rate for funds used by the corporate and the margin for risk adjusted return to equity. The estimation of the margin required has a lot to do with the business the corporate conducts and the extent of debt financing. Greater exposure should be accompanied by a greater margin. Furthermore some new business is riskier than others.

At this point the corporate can assess the risks of the business it is in by application of the capital asset pricing model (CAPM) or the arbitrage pricing model (APT)(Johnson 1992). The CAPM compares the return on capital in an individual firm with an index representing a portfolio of firms in a similiar industry or in all industries. The B coefficient measures the common variation between the individual and the group and this is the systematic risk component. The coefficient measures in effect the amplitude of the fluctuation in t'ˌ individual firms return compared with some average. A coe''icient greater than one indicates that the firm is subject to greater fluctuations than the average and hence is considered to be in a more risky product mix or industry group.

The corporate can then compute its risk adjusted required return on equity (K_e) by adding to its normal borowing rate (R_f) a margin based on the industry group margin (R_m) above the risk free rate times its B (Shim and Siegel 1986).

ie $$K_e = R_f + B(R_m - R_f).$$

In this way a corporate or industry can derive a risk adjusted rate of required return on equity that provides a safety margin for unforseen events suitable to its industry situation.

It is important to note that the approach for the public and private sectors is really quite different. The public sector is operating at a low risk level and should focus on the social costs and social returns. The discount rate can in this sense be relatively free from risk connotations. Public decision making would still benefit however from appropriate measures of estimation uncertainty. In the private sector operating risk and financial risk are realities of life and adequate margins need to be included in their investment analyses. A risk adjusted discount rate seems appropriate to this requirement and also seems to conform with a great deal of actual practice in the private sector. Estimation uncertainty still needs to be identified.

Part of Government financial reform in New Zealand is the imposition of a capital charge on government departments. For departments where outputs are deemed to be contestable, the department is expected to face the same incentives as for private sector participants. This principle also applies to the provision of services paid for by the Government. It follows from the above discussion that the charge should reflect the business risk of the department concerned. The question then is what is the kind of business that each department is engaged in?

The ingenious solution to this conundrum is to ask the department to examine what its core business is? "A department providing library or information services should not identify itself with the public utility sector when a significant part of their activities has more to do with the provision of accomodation or storage facility , or information technology. It would be better to match their activity with an information bureau or a property management activity". For the agriculture department (MAF) the exercise involved taking the weighted average of the risk exposure for revenues derived from meat inspection activities, disease and pest prevention activities, fisheries research and other fisheries activities, and other agricultural activities including policy advice. This involved identifying private sector companies with expos"re comparable to MAF's core activities.

Valuing Risk

Option pricing theory (OPT) provides mechanisms whereby changes in risk status can be evaluated (Johnson 1992). Investment in irrigation works, for example, changes both productivity coefficients and the certainty of return. It increases the yield factor and decreases the uncertainty factor. Investment analysis by DCF methods picks up the yield effect but ignores the risk effect. OPT offers the chance to evaluate both factors and also to tease out the implications for investors, both public and private.

OPT is analagous to a drought insurance problem. If dryland farmers could pay a premium to an insurer to remove drought risk from their production system, how much would the insurer charge? Thus a reasonable estimate of the reduction in risk is the difference in notional insurance premiums farmers would be willing to pay to insure dryland versus irrigated production.

Insuring against production risk is similiar to insuring against price risk. Previous studies have established the value of price support policies by estimating how much farmers would have to pay to guarantee the minimum price offered by a support programme (Seed and Anderson 1991, Bardsley and Cushin 1990). Any form of such a guarantee has similiar characteristics to a put option. A put option gives holders the right but not the obligation to sell a specified asset for a specified period of time at a specified price. Minimum price schemes also grant producers the right, but not the obligation to sell their production to the agency administering the scheme at the minimum price prevailing during a season. That is, the guarantee scheme, or option, is worth something if the market price is below the minimum price. Such a guarantee has a value independent of whether the market price fell below the minimum. That is, the guarantee itself has some "value" to farmers.

Likewise with forms of production insurance, the insurance in itself is worth something even though the farmer may not make a claim. The guarantee given reduces risk and that risk reduction has a positive value. In the case of irrigation investment, participating in a scheme guarantees some minimum level of production. This has a "value" to the participant as downside risk is reduced.

We attempt to estimate this value next using the data available in Table 1. The notional annual drought insurance premium is calculated as if it were a put option. Table 2 shows annual insurance premiums per $1000 of gross revenue insured for each farming system. These are calculated as the value of an "at-the-money" European put option assuming a term to expiry of one year, a risk-free rate of interest of 10 per cent, and a range of standard deviations from 10 per cent to 30 per cent. This only applies to drought risk and excludes any commodity market risk.

It seems clear that farmers would have to pay premiums of $28-30 per $1000 of revenue on dryland to obtain similiar variability to irrigation farmers. Applying such premiums to gross revenues expected per hectare in the dryland system it is then possible to estimate farm or scheme levels of the "value" of risk reduction. In this particular example, the scheme area is 7850 ha of which 1200 ha is crop. Table 3 shows the revenue data for different enterprise opportunities and shows that the "scheme" reduction in risk has an annual value of some $100000.

As Table 1 showed the NPV of the water in this scheme was around $15 m at 10 per cent discount rates ($1911 per ha). This is the present value of the extra productivity of the resources including water less the costs of achieving it. The NPV of the annual risk reduction premium at 10 per cent for 40 years is $985000 or say around $1 m. This is additional to the productivity gains and represents some 7 per cent extra "value" generated by the investment. This has implications for a set of investors interested in buying the scheme, for the departing owners of the scheme, and also for existing participants in the scheme who in effect were "paid" to join the scheme, as it affects the asset value.

Distribution of Benefits

In this particular scheme and others like it, the Government required a majority decision by landowners to take part and guarantee to pay for some of the water provided before scheme approval was given. No doubt increased certainty of farming was a useful argument to get farmers to join at this stage. The practice was for the State to subsidise the construction work and off-farm works and to recover costs (in part) from water charges. Farmers never paid the full historic cost of delivered water. Thus not only was water under-priced but the value created by increased certainty of yields overlooked. Some or all of both these benefits would have passed into land values or have been lost.

Before the investment, the land market could be regarded as stabilised fluctuating only as product prices and costs changed. Next the Government offers to provide water and subsidies. The land market would respond to the better expectations. The scheme is implemented and the under-charging regime commences. Production revenues rise and more even revenue flows are achieved. Farmers are free to leave the scheme. What will the land market do?

Clearly the NPV of the land factor (expectation value) will adjust according to the various impacts of productivity changes, assured yields, commodity prices, under-charging for water and cost inflation. All these impact on the net return to the land factor. Without doubt the increased assurety effect will be lost in all the other effects. It has not been recognised and it has not been priced. However we know from the calculations in the previous section that around 7-10 per cent of the value of water can be added to the notional land value to represent this effect. Obviously this supposition needs following up with further testing and refinement, but the potential gains are present for those who hold the land or wish to sell it. Once it is transmitted into land value, no further gain is possible.

If Government wishes to dispose of its interest in the scheme, it would be interested to know what the assets it owns are worth. Table 1 was prepared with this objective in mind. These NPVs did not include the surety factor. Thus the reduction of risk offered compared with dryland farming should enhance the selling value. (perhaps land values had already risen before this event and extra surety was no longer Governments to sell?) In the event, the NPVs shown in Table 1 were adjusted downwards to reflect the predominant pattern of sheep farming (ie water was to be priced at its lowest value use because water use rates cannot be price differentiated on different land use) and on-farm irrigation assets were written off. Even so, the negotiated price of the scheme was even further below such adjusted NPVs ($0.55 m).

Other explanations need to be sought for such under-pricing of the assets, including the lack of competition among buyers and the Government willingness to dispose of a loss-making asset only to farm stakeholders (perhaps this can be explained by considerable differences between the financial cost of retaining the scheme in Government possession and the positive value of water application which necessarily accrued to the existing landholders?).

From the point of view of the farmers as buyers of the scheme, the enhanced yields and surety had already passed into their hands through the Government under-charging policy for water. Those who had left farming had turned their gains from subsidy into capital. Further details of the transaction itself is required if one was to be able to isolate just what asset was left to buy at sale time given the previous history of under-charging and subsidisation of head works.

Conclusion

The burden of the argument in this paper has been to make more explicit the uncertainty associated with the use of forecasting data in <u>ex ante</u> investment analysis. This involved setting a standardised basis for evaluating uncertainty in input variables. Most likely values must be converted to expected values. There must be some standardisation of procedures in making assumptions about input uncertainties. Decision makers must be made aware of the assumptions that made up single point estimates commonly fed into them. Education is important for decision makers. Even analysts benefit from more careful scrutiny of the data they use every day.

There is a distinct difference in the public and private approach to discount rates. Public CBA is concerned with social costs and returns and can assume low risk margins. Private CBA must be concerned with the risk-adjusted return on equity and can adequately express this through risk-adjusted discount rates possibly aided by the CAPM.

In some investments, investment changes the risk profile. Such distinctions should be incorporated in the with and without analysis. The risk analysis presented in this paper can identify changes in the risk profile. Risk reduction has a positive value to the owners of the relevant resources. In the case study presented here it is not clear who the beneficiaries are from risk reduction.

References

Baru ley, P. and P. Cushin, 1' 0, 'Underwriting Assistance to the Australian Wheat ' .. try - An Application of Option Pricing Theory', .ralian Journal of Agricultural Economics, 34 (3) -222.

Bell, B. 1977, 'Analytical Risk Evaluation', Technical Paper 7/77, Economics Division, Ministry of Agriculture, Wellington.

Forbes, R. 1984, 'Cost Benefit Procedures in New Zealand Agriculture' Ministry of Agriculture, Wellington.

Forbes, R. 1990, 'Product Price Assumptions' Ministry of Agriculture, Wellington.

Forbes, R. 1992, 'Application of the Stochastic Budgeting Model (SBM) to the Wanganui Hill Country Class 4' Technical Paper 92/12, Ministry of Agriculture, Wellington.

Johnson, R.W.M 1992, 'Risk and the Farm Firm: A Corporate Finance View' Review of Marketing and Agricultural Economics, 60 (1) 9-22.

Seed, P. and G. Anderson, 1991,'Option Pricing Theory and the Value of the New Zealand Wool Boards Minimum Price Scheme', Conference of the NZ Branch of the Australian Agricultural Economics Society, Lincoln University.

Seed, P., R. Forbes and R Johnson, 1992,'The Measurement of Risk in Agricultural Investment: the Case of Irrigation', Conference of the NZ Branch of the Australian Agricultural Economics Society, Waikato University.

Shim, J. K. and J. G. Siegel, 1986,'Theory and Problems of Managerial Finance', McGraw-Hill, Auckland.

SriRamaratnam, S. and M. J. Arthur-Worsop, 1990, 'Water Management and Risk Modification', Report 89/20, Rural Policy Unit, MAF Policy, Wellington.