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APPROACHES TO RISK ANALYSIS IN PROJECT ECONOMICS

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Abstract: This paper focuses on the available techniques for dealing with the outcomes of unknown events in project design and economic analysis. It begins with a conventional definition of the terms risk and uncertainty followed the methods for dealing with the existence of project outcomes which can only be modeled as uncertain, rather than risky. We then present a critical view of the techniques available for modeling risk on the basis of probability distributions.

1. RISK AND UNCERTAINTY

The terms “risk” and “uncertainty” are applied generically to the analysis of situations with unknown outcomes. We adopt here the conventional distinction between risk and uncertainty made in literature. According to it, in essence, risk is a quantity subject to empirical measurement, while uncertainty is of a non-quantifiable type. In a risk situation it is possible to indicate the likelihood of the realized value of a variable falling within stated limits – typically described by the fluctuations around the average of a probability calculus. In situations of uncertainty, the fluctuations of a variable are such that they cannot be described by a probability distribution.

Thus, risk and uncertainty are best thought of as representing a spectrum of unknown situations with which an analyst may be dealing, ranging from perfect knowledge of the likelihood of all the possible outcomes at one end (risk) to no knowledge of the likelihood of possible outcomes at the other (uncertainty).

It is not the real-world situation itself, which is either risky or uncertain, but merely the information available to planners and analysts, which defines it as such. All actual project outcomes are unknown, because they occur in the future and are subject to influence by a number of variables, each of which may take different values. If we have reliable historical or forecast data such that a probability distribution can be constructed for such variables, the situation can be modeled as risky. If we do not have such data we can only describe the future in terms of uncertainty.

For example, analysis of an energy project may be undertaken in terms of “optimistic” or “pessimistic” assumption about domestic and commercial power demand level (and different returns predicted under such different scenarios), or may be modeled on the basis of a distribution of outcomes of future power demand which itself depends upon estimates of economic growth, population growth etc., and which may be described on the basis of their probabilities of occurrence. In both cases there is nothing inherently different about the circumstances of the projects themselves, only the data available to the analyst which makes modeling of risk more or less possible.

This distinction between risk (unknown but quantified outcomes) and uncertainty (unknown and unquantified outcomes) is not usually so clearly made in typical financial analysis. UK Treasury Taskforce, for example, quotes the following definition of risk:” A simple definition of risk as used by the accounting profession is uncertainty as to the amount of benefits. The term includes potential for gain and exposure to loss.”

Such a distinction (mentioned above) is in fact very useful because it helps to separate those situations which may be subject to quantitative analysis from those which are not.

2. MODELING UNCERTAINTY

Project economic analysis tries to allow for existence of unknown future outcomes in the most basic sense by modeling the existence of uncertainty rather than dealing with risk per se.

Attempts to model the impact of uncertain outcomes and develop decision rules about what choices to make (for example, between different projects or alternative project designs) derive from the operations research (linear programming models) and game theoretic (von Neumann, Morgenstern) approaches of the 1960s and 1970s. In situations of different possible project alternatives and uncertain future events ("states of nature"), project would be chosen on the basis of various proposed criteria, according to decision-makers' preferences. Such proposed criteria are:

a) Laplace – select the project or design alternative which yields the highest return, whatever the "state of nature" obtains

b) MAXIMIN – select projects or design alternatives which yield the best returns (e.g. the highest NPV) if the situation/"state of nature" turns out as badly as possible

c) MINIMAX REGRET – select the project which minimizes the maximum opportunity cost of having made a wrong choice by choosing s "state of nature" which does not in fact obtains.

It can be proven that such criteria are in fact all "irrational" in different ways. The Laplace criterion effectively ignores uncertainty altogether, the MAXIMIN assumes "nature" to be as malevolent as possible and the MINIMAX REGRET does away with normal assumptions about decision-makers' preferences (because they are more concerned about minimizing losses ex post than about maximizing returns ex ante).

Despite some historical applications for planning purposes, for such reasons as just given, game theoretic criteria were largely abandoned as models of descriptive or prescriptive behavior and has largely concentrated on describing unknown outcomes alone, without attempting to derive decision rules to guide choice under certainty.

The most used technique for describing uncertainty is sensitivity testing. In essence, it involves changing the value of one or more selected variables which affect the project's costs or benefits and calculating the resultant change in the project's NPV or IRR. There are recommended practices such as:

- Testing for the effects of changes in aggregate project costs and benefits
- Testing for the effects of changes in individual underlying variables (areas, yields, prices of cement , operating costs of machinery in a roads project or consumer utilization rates in a power or water supply project)
- Testing variables one at a tome, so as to be able to identify the ones with most impact on project NPV
- Testing for delays in benefits or implementation
- Testing likely combinations of variables (especially if these may in practice be linked, and
- Testing for changes in economic pricing adjustments (e.g. shadow wage rate factor, shadow exchange rate factor, standard conversion factor etc.)made by the analyst

Sensitivity testing leads to the calculations of switching values (SVs) and sensitivity indicators (SIs):

- SV identifies the percentage change in a variable for the project NPV to become zero (i.e. for the project decision to switch between accept or reject, average yields would have to fall by 20%); sometimes SVs are expressed in terms of the absolute value of a variable

- SI compares the percentage change in a variable with the percentage change in a measure of project worth (NPV or IRR).

The main utility of sensitivity testing is that it leads to the identification of those variables to which a particular project design is most sensitive, and mitigating action can then be taken to minimize the consequences of such outcomes. Likely mitigating actions include undertaking pilot projects, securing long-term supply contracts, increasing technical assistance and training levels to support project implementation etc. The technique is very easy to apply, as changes to one value in a spreadsheet will reflect instantly in values for NPV, IRR etc.

The sensitivity testing technique has a number of limitations:

a) most fundamentally, it does not take into account the probability of the occurrence of the events it models

b) where deviations from project "base case" estimates are modeled in sensitivity testing, it is not clear whether the variations in values which are being modeled are changes from "expected" values or are deviations from "most likely" (or modal) values;; depending upon the characteristics of particular distributions, mean and modal values may be very different one from another, and what is being captured in the base case and its variation is not clear

c) the identification of appropriate groups of variables to vary together depends on specialist knowledge, and misunderstanding the nature and extent of correlation between variables can lead to erroneous results; and

d) because the distribution characteristics of different variables which determine project outcomes can differ very much (for example the variability in commodity prices is less than input prices, the variability in power demand is less than in generation etc.), the use of standard percentages for variations in sensitivity testing captures quite differential extents of likely variability. An impression of homogeneous variability is given, which is not warranted by reality.

We have to mention a very important issue regarding to modeling uncertainty in project economic analysis. It is sometimes suggested that uncertainty can be allowed for by either applying a different discount rate in the calculation of NPV or by using a higher cut-off rate for investment decisions. While there is a large theoretical literature on this point, in essence there is no justification for this approach – apart from any other consideration, it assumes that risk always increases with time, which is not necessarily true. The discount rate is a rate of decline in the numeraire of economic value, and has nothing to do with the source of risks facing an investment.

3. MODELING RISK QUANTITATIVELY

Because of the conceptual shortcomings of all approaches to modeling uncertainty, various attempts have been made to properly capture the impacts of unknown outcomes through modeling risk quantitatively in project economic analysis.

The purpose of quantitative risk analysis in essence is to provide a means of estimating the probability that the project NPV will fall below zero, or that the project IRR will fall below the opportunity cost of capital.

The results of sensitivity testing can be used to consider which variable(s) may be appropriate to base a risk analysis upon (those that have major impacts on project outcomes). Having identified particular variables, a number of possible data points (i.e. values above and below the "base case", upper and lower limits to data values, etc. are necessary to be specified, together with the frequency (or likelihood) of each of these values occurring. From such data points and associated frequency estimates, a probability distribution can be constructed for the variable(s) in question.

It should be noted that identical procedures to these can be applied to projects where expected NPV is not typically calculated (e.g. education and health projects which use measures of cost-effectiveness of outputs or impacts (e.g., annual cost per health worker employed, cost per primary school pupil educated) quoted together with distributions for those values.

Risk analysis typically involves the choice of several variables to be varied simultaneously, as project returns are generally subject to more than one source of risk. Because of the mathematical complexity involved in such calculations, the analysis of risk in this form is invariably undertaken by some kind of computer software. The process which is followed (and which is usually referred to as Monte Carlo or simulation analysis) is that values for individual variables are generated randomly according to their respective probability distribution, combined with other randomly-generated values for the other variables, and these figures are used to calculate an estimate of the project NPV. This process is repeated a large number of times (a number which is specified by the analyst – in effect equivalent to implementing the project again and again in different circumstances – and is usually at least 1000 times, and typically more than this) and an average (or expected) NPV is produced together with an associated probability distribution.

The early literature on risk modeling and also standard texts on project appraisal, all mention the fact that computer time and expertise is likely to be a major constraint to the use of this technique. In recent years this constraint has largely been overcome and more than adequate computational facilities and software are now available to practitioners.

4. TWO CONSIDERATIONS ON RISK ANALYSIS

Despite the overcoming of computational limitations to the application of such techniques, two major practical considerations remain as regards the extent to which such techniques as Monte Carlo simulation can be used in project preparation situations.

The first is the issue of data availability, and the extent to which the situation can reasonably be defined as risk 9as opposed to uncertainty) through the construction of a meaningful probability distribution of outcomes. The actual situation with data availability is likely to vary very much both between project situations and also across different sources of variability within any one project environment. At one extreme, large volumes of reliable cross-sectional or time series data may be available from historical sources for the variable concerned (e.g., for rainfall, for commodity prices, for traffic flows). At the other extreme may only be the existence of a few data points (e.g., most likely values, absolute minimum possible, maximum possible etc.) which are expectations of experts or analysts involved in preparing the project. Other possibilities lying within these bounds include the forecasting/specification of power-generation theoretical capabilities adjusted for a set of likely different operating conditions, forecasts of trade flows and commodity prices etc.

It is important to note that very large and complete data sets from empirical sources are not always necessary for the undertaking of risk analysis. Simplifying assumptions about variable distributions can be made – as a bare minimum, triangular distribution from three points (most likely, minimum possible, maximum possible0 can be constructed based on “best guesses” of project preparation team members. There is also often considerable expertise within the project preparation environment about the likelihood of variables or outcomes which may be not available from official sources but which can be elicited from potential project participants. The Delphi method of eliciting opinion from local experts is an example of this type of approach, and has been applied in a probability-based form by World Bank in a risk analysis of institutional reform in the irrigation sector in Pakistan.

Well-tried empirical methods exist for developing probability distributions from such subjective sources. These include visual impact techniques (e.g., matches or stones piled up to represent frequency of value occurrence), structured questions to identify key points in a distribution (e.g., the median, quartiles, etc) and the application of “smoothing” techniques in situations where a few real data points may be available.

Some proponents of probability-based risk analysis argue that the shapes of particular distributions of individual variables are less important than the choice of variables themselves, which are allowed to be modeled. Recent experience of preparation of power projects suggests that the particular form of distribution matters less if a large number of simulations are run. Even when considerable effort is made to replace, for example, the quoted discrete distributions with relatively few values by continuous distributions based on large amounts of empirical data, there is little difference in resulting distributions of EIRR/ENPV outcomes (i.e., expected values and variance, minimum and maximum values, etc).

This approach may not always be appropriate for all variables, and it still requires judgment on the part of the analyst about what ranges are acceptable for values to fall within. Also, to adjust the spreadsheet model to produce a normal distribution (as opposed to a uniform one) becomes very much more complex. It is also noted in the risk literature that there is no a priori case for the use of normal distributions as all variables are not always subject to relatively large number of random influences.

The techniques applied to develop definitions and derivations of probability distributions for individual variables in most cases is likely to depend upon some subjective judgment by an appraisal team – and inevitably the extent to which these design assumptions adequately reflect the reality of the project will vary from case to case. The suspicion that what appears as a full-scale risk analysis has in realty only a spurious precision can be ultimately only fully allayed if the data upon which the variables’ probability distributions are constructed are believable.

The second consideration when applying risk analysis in practice is the extent of covariance between those variables that are to be selected for risk analysis. Projects are rarely subject to only one source of risk, and therefore more than one variable at a time is modeled in the Monte Carlo simulation expertise. Statistical complexities can arise depending upon the relationship between the selected variables. Where variables are in fact statistically independent of one another there is no problem, as it is appropriate to treat them independently. Where variables may be thought to be related in some way, the extent of covariance between them needs to be taken account of when specifying the distribution of individual variables in some type of simulation.

For example, project revenues are typically products of both quantities sold and prices obtained. If these underlying variables are correlated in some way (which may well be if project output is large relative to market volume, and negatively so in this case) the expected value of the product of two random variables (i.e. project revenue) is equal to the product of the individual expected values plus the covariance between the two variables. Another typical example of covariance may be that between area planted and average yield (i.e., with both variables as determinants of farm production volumes). In practice, the approach to assigning particular levels of covariance between variables is quite pragmatic, and typically simple rank correlation coefficients between pairs of variables are sufficient for most purposes.

It is specifically recommended that disaggregation of individual variables be limited as much as possible so as to avoid including too much correlation in the analysis. For example, although individual construction cost items e.g., cement, cost of floor, cost of walls) may each be thought to vary individually, in reality the sources of this variability all arise from one point (e.g., cost of imported cement), and this could be most appropriately captured through some item such as "construction materials" rather than by introducing additional correlation between such items (which would tend to increase unnecessarily the estimate of overall variability). Akin to the nature of some subjective judgment being involved in the allocation of probability distributions, there is therefore a similar judgment to be made about the extent of dissagregation to be applied in individual circumstances.

CONCLUSIONS

It is clear that the quantitative modeling of risk is in principle preferable to the simple depiction of uncertainty, although it is obvious that data and time considerations and the difficulties in properly identifying and specifying covariance among variables, have often limited the extent of actual risk analysis practice. It is also the case that the present availability of computer software to easily process Monte Carlo-type simulations from data already available to the analyst within spreadsheets, plus the existence of statistical routines and computational processes to fit probability distributions to many data sets, greatly increase the possibilities for application of quantitative risk analysis as a more commonplace part of project design.

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