QUANTIFYING LONG RUN AGRICULTURAL RISKS AND EVALUATING FARMER RESPONSES TO RISK

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THOUGHTS ON RISK ACCOUNTING IN PUBLIC PROJECT APPRAISAL

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Background

Subsequently joined by my colleagues John Dillon and Brian Hardaker, I labored in 1973 during a sabbatical leave in India to put together a manuscript which ultimately appeared in 1977 as Agricultural Decision Analysis. There were the inevitable reasons for the slow production of the book but, looking back on it all from the distance of the 90s, I have two main regrets about it having appeared as it did in 1977. The first was that this was the year in which the pioneering articles by Jack Meyer on generalizing the concept of stochastic efficiency appeared and these were, unfortunately, unknown to us when we put our manuscript "to bed" in 1976. This unfortunately meant that, what was until then, I think, a quite novel and contemporary treatment of stochastic efficiency in agricultural decision analysis immediately became somewhat dated, because of the considerable advantages that stem from using the extended concepts of stochastic efficiency and the added power of using more confined ranges of absolute risk aversion in order to analyze the impact of risk in many classes of decisions.

The second regret associated with the 1977 year of publication was that our chapter dealing with investment decisions under risk did not have the benefit of us having read what I judge to be the seminal paper prepared and published in mimeographed form by Robert Wilson in that year. I think Wilson's article stands out as the definitive analysis of risky investment decisions and it would have been nice to have synthesized some of his comprehensive treatment into our expository text. Wilson's paper eventually appeared in the proceedings volume of Lind et al. (1982) and is thus now widely accessible to the profession although, as I observe casually, seems not widely used by our peers.

The particular class of investments of interest to the public sector received a solid dose of attention in the early 70s through a series of articles mainly in the American Economic Review. The seminal work in this saga was that of Arrow and Lind (1970). They argued persuasively that explicit accounting for risk in pure public projects was, in most cases, unnecessary. There have since been many reaffirmations of this general principle, which thankfully can be regarded as no longer controversial. The thing of potential interest for the present huddle, however, is the "exceptional cases" identified during the 1970s as warranting special attention.

These exceptional cases were clearly identified by Ian Little and James Mirrlees and their contemporary refiners of modern methods of project evaluation

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as they assembled their compendiums of guidelines in the early 1970s. For instance, the Little and Mirrlees (1974) book noted two major special cases and the adjustments that might be made for them. These were, respectively, the "large project" case and the "correlated project" case. They derived, respectively, second- and first-order Taylor-series approximations for making a simple adjustment to (usually a deduction from) project mean valuations to allow for the lack of certainty. The "size" deduction (D_1) and the "jointness" deduction (D_2) are, respectively, encapsulated in my dimensionless versions of these two formulae:

(1) $$D_1 = Ac_X^2R/2,$$

and

(2) $$D_2 = Ac_X\rho c_Y,$$

where the D_i are expressed as fractions that should be subtracted from the mean value of a risky project and where A is the assumed constant level of relative risk aversion, c_X is the coefficient of variation of project return, R is the relative size of project expressed as the ratio of mean project return to mean national income, ρ is the correlation between project return and national income, and c_Y is the coefficient of variation of national income. To the extent that clear trends in the component variables and those that influence them are known and thus do not contribute to risk (as opposed to variability), they should not contribute to the risk adjustment process.

Foreground

There are obvious similarities between these adjustment formulae and some of Wilson's (1982) results based on normally distributed random variables and constant risk tolerance, r, the inverse of the absolute risk aversion coefficient. In particular, his equation (50) defines a risk charge, H, in absolute units of project return as

(3) $$H = (1/(2r))[\sigma_X^2 + 2\sigma_X\sigma_Y\rho_{XY}],$$

where the subscripts are as above and the σs are standard deviations. I prefer to express this equation in dimensionless terms analogous to (1) and (2) but, to do so, must shift gears to relative risk aversion and other relativities. By definition, r = W/A, where W is the wealth of the agent, and if the convenient assumption is made that a surrogate for W is mean national income, equation (3) can be re-written by expressing H as a fraction, D, of mean project return as

(4) $$D = A\ c_X(c_X\ R/2 + \rho c_Y),$$

in which case

(5) $$D = D_1 + D_2,$$

which thus provides a fortuitous link to the Little and Mirrlees (1974) results which were based on a constant-relative-risk-aversion utility function. As equation (3) is based on normality and constant absolute risk aversion, there is an element of the magic wand in shifting gears, which I rationalize by claiming that constant relative risk aversion seems to be a reasonable general assumption and that, for wealth levels that are not changing too vigorously, absolute risk aversion will be locally more or less constant.

To me, equation (4) provides an adjustment device of elegant simplicity, fair theoretical plausibility and strong intuitive appeal. Before getting too carried away with it in applications, however, it would be reassuring to know that it is also empirically robust. This question was addressed (Anderson (1989a) through a small Monte Carlo experiment using the family of constant relative risk aversion functions for a range of levels (0.1 through 3) and simulated projects and national economies spanning a range of relative sizes (R, 0.01 through 0.25), variabilities (c_X, 0.1 through 1.0; c_Y, 0.01 through 0.2), and correlations (ρ, -1. through +1.). Proportional risk deductions were computed from sampled certainty equivalents evaluated by inverting the designated utility function at sampled mean utility. Writing the certainty equivalents for national income with and without project as CE_X and CE_0, respectively, the sampled proportional deduction, d, was defined relative to mean project return, E_X, as:

(6) $d = 1 - (CE_X - CE_0)/E_X$.

A complete factorial design with 1080 treatments was used to examine values of d for the sample space of the experimental variables. In a first experiment, approximate (i.e., slightly truncated) bivariate normality of X, Y was assumed. Regressing the sampled values of d in (6) on values of D computed according to equation (4) yielded a coefficient of determination of 0.96, supporting the applicability of (4), notwithstanding its gear-shift from (3) via the different utility function.

Robustness with respect to departures from normality was explored in a limited way in a second experiment in which the marginal distribution of X was specified as approximately lognormal and, because correlation was incorporated by means of Kleijnen's (1974) method, the national income marginal distribution was indeterminate. The happy result was that equation (4) still described the sampled data very adequately (0.92) and better than any of a variety of arbitrary formulations involving the same explanatory variables.

In short, proportional risk deductions computed according to equation (4) do seem to be applicable and reasonably robust, and nicely encompass the two earlier acknowledged exceptional cases captured by D_1 and D_2. Thus the elements of (4) constitute something of a minimal data set for risk analysis. Relative risk aversion plays an obvious "up front" role. It can safely be presumed to lie in the range of 1, for typical cases, to 2 or so for more risk-averse situations, such as can expected to be encountered in much of the developing world. Capturing project riskiness largely through c_X is clearly minimal but it is impossible to think of any other single statistic that could do the job as well, and a similar consideration applies to c_Y. The final, surely most subtle, and certainly most estimationally demanding element is ρ. It is, of course, unthinkable to have a risk adjustment procedure for a project that does not include accounting for how the project contributes to overall risk through either its covariation with the rest of the economy, ρ, or its magnitude relative to it, R.

Practice Ground

Notwithstanding the clear articulation of these adjustments, they seem to have been little used by project evaluators in the fifteen or so years since the publication of the guidelines. This may seem surprising but is probably explicable largely through the difficulty perceived in providing some of the key elements in the formulae. It is, indeed, no small task to compute a cogent summary measure of risk such as the coefficient of variation of project return. In most cases a well conceived and calibrated stochastic simulation model of the project's structure would be required to provide a defensible handling of the many risks that inevitably pervade projects. Such models are still somewhat expensive to construct and presumably analysts, by their demonstrated proclivities, have judged the costs to be inadequately compensated for by anticipated benefits. This is also somewhat surprising since there was quite a flurry of activity under the broad heading "risk analysis" in the management science literature of the 60s and early 70s in which methods were exposited that lend themselves to low-cost computational procedures for generating relevant probabilistic information (e.g., Hertz 1964, Wagle 1967), most often presented in the form of CDFs of project return. Some of this activity also took place in public investment agencies such as the World Bank, as illustrated by the didactic papers prepared by Reutlinger (1970) and Pouliquen (1970). Although the computational cost of producing such summary probability distributions has surely dropped considerably since these early expositions, the extent of practice of such risk analysis in public project appraisal seems minimal and close to zero.

Thus we have the situation of (a) apparently well-refined analytical methods, (b) clear recognition of when risk accounting is appropriate, and (c) potentially useful applications, yet (d) minimal uptake in practice. How can all this be reconciled?

I stumbled into this situation in an earlier short visit to the World Bank in 1983 when my friend Ron Duncan in the then Commodities Division was asking the question: What should the World Bank be doing about recognizing the lack of precision inherent in the periodic forecasts it makes of prices and quantities of major commodities of interest to the World Bank. To get a handle on this question it is necessary to step back and ask first what information would be needed if appropriate risk analysis was to be undertaken by project analysts, and so these two considerations are closely linked in both theoretical and empirical dimensions.

My analysis at that time strongly supported the Arrow-Lind position in most cases but I did attempt to develop what I regarded as pragmatic and workable procedures for the exceptional cases. I called my suggestions a "rough and ready" approach that could be applied after a conventional (certainty-implied) project appraisal. It consists of seven steps, namely:

1. Choose a 'representative' early period in the life of a project when returns and costs should have 'settled down' (t^*);

2. Estimate the ratio (R) of mean project return to mean GDP (or other more local measure of aggregate income or economic performance judged to be most relevant) for this period;

3. Elicit the simple correlation between project return and aggregate income (ρ) and estimate the coefficient of variation of aggregate income (detrended), namely c_Y;

4. Assess the mean and standard deviation (or coefficient of variation) of all major uncertain variables (prices and quantities) for this period;

5. Compute a rough estimate of the coefficient of variation of net project return (c_X) for this period;

6. Compute, by means of reference to equation (4) or somesuch, the proportional risk adjustment for the period P_t^*;

7. Decide if this is 'significant' (say > 0.01) and:

(a) if so, adjust (multiply) estimated expected net present value by the factor ($1-P_t^*$) to give a crude risk-corrected or certainty-equivalent present value; or

(b) if not, conclude that, in this instance, uncertainty has no worrying impact on the appraisal and, accordingly, proceed to ignore it and base the investment decision on the certainty appraisal.

The gross simplifications embodied in this sequence are all too obvious. The idea of a 'representative period' greatly simplifies the process but at the cost of ignoring (a) uncertainties in the developmental phases early in the life of the project, (b) uncertainty about the life of the project, (c) serial dependencies among the uncertain variables (bias from this omission is probably in the direction opposite to that inherent in ignoring (a) and (b)), and (d) of representing so crudely the interdependence with the rest of the economy.

Yet this rough and ready method is not as costless as may be apparent at first blush. Step 4 may involve considerable new data gathering (e.g., on probability distributions for forecast prices) and/or subjective elicitation. Step 5 is not too difficult if not too many of the project components are uncertain (whence the simplifying formulae of Anderson and Doran (1978) and Anderson (1989a) Appendix 1 can be used) but can be a little more cumbersome if several mutually dependent variables are involved in which case a Monte Carlo approach must be used (Anderson (1976) provides one such a program).

The heart of the method is Step 6 which, in turn, depends on the values determined in Steps 2, 3 and 5. It also depends on the level of risk aversion that is really appropriate. In a really rough-and-ready approach, this issue can be dodged by presuming, in equation (4), that relative risk aversion A is, say, two.

The immediate extensions to this simplest version of the present approach are still fairly 'rough' but the 'ready' advantage diminishes rapidly. There is a clear scope for honing the estimation in Step 3. Extending the temporal coverage beyond the representative single period has obvious consequences for additional information on n periods (i.e., at least n times the one-period case) but, in addition, has the less obvious requirement of explicating interperiod (particularly intertemporal correlation) effects which may be both demanding of specification and important in consequence. More comprehensive stochastic specification in Step 4 can lead to 'better' probabilistic description, but at possibly considerable informational cost (Anderson 1974). To go beyond the pragmatism implicit in Step 6 requires rather more expensive forms of analysis, such as described by Anderson, Dillon and Hardaker (1977, Ch.8), Keeney and Raiffa (1977) and Meyer (1977). But this is a story for another time and, preferably, another person.

Other Ground

The ground here is so little cultivated that it is probably a fertile one for sowing new seeds of analytic endeavor. For instance, it occurs to me that the outlined procedures may be directed at private and even personal project approval as well as the public ones discussed above. In such case Y would be interpreted as, say, an individual's income without taking on a marginal project, and the corresponding minimal data set would then be used to provide guidance as to whether the project is worth taking on. Depending on the individual and the situation, higher values of A may well be applicable (e.g., for a resource-poor peasant contemplating investment in a new process proclaimed by authorities to be "improved."

Whatever the level of application, a continuing empirical difficulty relates to estimating or eliciting correlation coefficients. Estimates of ρ in equation (4) play a key role, for instance in determining the sign of the risk adjustment D. Ceteris paribus, a sufficiently negative ρ will reduce overall risk to such an extent that the certainty value of the project must be adjusted upward. Specifically, when

$$(7) \quad \rho < -(1/2)R(c_X/c_Y),$$

i.e., the correlation is less than one-half of the product of relative size and relative risk, risk adjustment will be positive. A practical difficulty, however, is that estimates of correlation coefficients from small samples are notoriously labile. On the other hand, subjective elicitations are variously notoriously difficult, unsatisfactory or impossible. When faced with the task of distilling a prior from the inevitably vague inner feelings of uncertainty, courage must be gained from the thought that the probability of the correlation being precisely zero, or unity or, even less plausibly, negative unity, is so remote as to be effectively zero.

I do not pretend to have answers to this challenging question of method. What I see is ample opportunity for novel methodological developments for translating subjective appraisals of "jointness" into analogs of moment-based correlation coefficients. I was never too happy with my last cut at this (Anderson, Dillon and Hardaker 1977, Ch.2) either via (a) intervalized and tabulated bivariate empirical distributions or (b) judgmental-fractile-elicited structured marginal and conditional distributions for the multivariate normal case -- but then it became lost in my "too hard" files.

A further underplowed ground I'll mention here briefly concerns insights for my topic that may be gained from the field of financial economics. A start has been made in this direction by Avinash Dixit and Amy Williamson (1989). They developed a model of project risk accounting that is analogous to the CAPM, featuring joint variation in the real exchange rate, price shock and productivity shock for a commodity, and national income. Data for many countries and commodities were processed in time-series analysis to yield data for determining risk adjustments. Following the CAPM, they worked in rates of return and, after invoking lognormality in the observed returns distributions, along with a few other simplifying approximations, they computed risk adjustments according to several formulae -- the simplest and most transparent of which is

$$(8) \quad Z = Ac_x \rho_{xY} c_Y,$$

where Z is the excess of expected project return over the riskless rate, and x denotes the "project shock," approximated, for example, by residual variation in price times quantity of a commodity.

This adjustment is clearly similar to D_2 in equation (2) and thus also the second term of D in equation (4), and thus scores highly on grounds of simplicity, theory and intuition, as well as providing some confidence-boosting partial support for the earlier approach. I just wish I could believe it, for it would make life so simple for the would-be risky project analyst. For me, the most important omission in equation (8) is any sort of size-of-project effect which, for my intuition, should enter somewhere in project risk accounting. Others will have their own intuitive requirements and can perhaps be enticed to delve into the CAPM and ICAPM worlds in search of fresh insights.

Finally, there is doubtless a certain naivety implicit in applying a single and rather general formula such as (4) in computing risk adjustments. For minimal internal consistency, variables should be defined on a broadly comparable basis, which harks back to a set of definitional issues that, for brevity, were swept aside in introducing all the adjustment formulae. If we begin from the left-hand side of equation (4), for instance, the proportional deduction is to be applied to the "value" of a project. For most purposes, the most satisfactory measure of value is the net present value assessed at the decision moment. Following this line, all the right-hand-side variables should also be based on present value assessment of the respective variables. Risk aversion A is the only variable that is not complicated by such an interpretation. The simplest element of those requiring present-value interpretation is R, which becomes the ratio of project expected present value to the expected present value of aggregate income over the life of the project.

The remaining three elements, c_X, c_Y and ρ are all intrinsically more difficult to assess in present-value terms because such summary statistics should, in principle, depend, inter alia, on the underlying intertemporal correlation structure. That this topic receives such scant consideration in expositions of risk analysis (e.g., Hertz 1964, Reutlinger 1970) suggests that it is largely overlooked in those applications that have been made (an exception is Hull (1980)).

If risk analysis is approached via a multiperiod stochastic simulation approach, c_X interpreted as the coefficient of variation of the present value distribution can be computed from the usually-reported cumulative distribution function for present value (CDF(PV)). Such models, however, have seemingly rarely (possibly never) included explicit modeling of the macroeconomy in order that c_Y, presently to be interpreted as the coefficient of variation of net present value of national (or other aggregate) income over the life of the project, can be comparably computed, along with ρ, the corresponding correlation between the two present value-variables.

Indeed, there is a logical dilemma in this analytic scenario. If comprehensive intertemporal modeling of the type discussed in the previous paragraph is engaged in for risky project appraisal, apposite utility functions and stochastic structures can be embedded directly in the model itself and expected utilities computed directly, obviating completely the need for "rough and ready" adjustment formulae such as (4).

To summarize, with ample time and resources, a full-blown risk assessment devoid of approximations can, at least in principle, be undertaken. In the more usually encountered reality of scarce time and highly constrained analytic resources, any decent attempt at risk accounting must involve the use of some type of approximation procedure such as is epitomized by equation (4). It then becomes an empirical question as to how well the conceptual present-value variables can be represented by selected single-period counterparts. This question can, in turn, be answered only by targeted case studies that would seem to lend themselves well to Monte Carlo methods.

Burialground

I'm tempted to close this discursive discussion with an early expression of hope that has, I judge, not yet been realized (ODA 1972, p.38):

> "It is to be hoped that research may in time throw light on the relative importance of the factors which are intuitively involved in determining the acceptability of risk and on the existence of limits on possible values of the parameters. This would allow a check to be made on the reasonableness of any particular set of rules such as those given above."

In sharing my thoughts, confessions and suggestions, I'm conscious that the-state-of-the-art of risky project appraisal has not yet reached a very satisfactory stage and has certainly not peaked out. This state reflects a seeming absence of intellectual curiosity brought on by muffled signals from the project-appraisal community implying that there wasn't a problem deserving of attention. I think the mood is changing and that we can look forward to a rekindling of the analytical fires of cogent human capital such as that which propels and sustains the S-232 Project. I wish you luck with it.

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