A DISTRIBUTION BASED APPROACH TO DECISION RISK ANALYSIS

by

John E. Ikerd
University of Georgia

and

Kim B. Anderson
Oklahoma State University

Submitted for Review
February 1986

For Presentation at
AAEA 1986 Summer Meetings
Reno, Nevada

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Abstract:

Risk management is the key to profitable decision making. Effective risk management requires integration of production, market, and financial risks in the decision making process. Simplicity and accuracy were the primary criteria used in selecting an approach to risk analysis for use in a wide variety of decision oriented educational programs.

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The objective of the work reported in this paper was to develop an approach to risk analysis that could be integrated into a wide variety of decision oriented extension programs for agricultural producers. The ultimate objective is to assist producers in making more effective decisions. Such an approach must be simple enough to be taught to and understood by farmers and ranchers. In addition, it must be capable of accurately reflecting risks confronting agricultural producers in their decision making process.

Expected values have been used extensively in past programs to teach decision making. The concept of expected value gives explicit recognition to the possibility of outcomes other than those deemed most likely. However, expected values, although necessary, are not sufficient to evaluate risks associated with alternative decisions. Enterprise budgets may include ranges of possible yields and costs, in addition to expected values, but rarely show probabilities needed to assess risks associated with enterprise decisions. Market outlook reports often show price ranges, in addition to expected values or point estimates, but rarely include probabilites associated with price ranges. Financial balance sheet and cash flow projections almost always rely on expected values, or point estimates of admittedly uncertain future outcomes. But, producers need quantative measures of chances and risks associated with possible outcomes better or worse than their expected values. They must be able to weigh the chances for profits against the risks of loss.

Risk management typically has been treated as a separate subject rather than an integral part of the decision making process. But, even these specialized risk management programs have found only limited acceptance and use. Probabilistic pay-off matrices are common in college classrooms but are rare if not extinct in real world decision risk analysis. Probabilistic decision trees have found wider use among extension economists but still are not used routinely in analysis of decision alternatives.

Typical market risk management programs focus on futures or options markets but provide no assessment of the magnitude of total risk reduction made possible with such tools. Production risk management programs often deal with such topics as crop insurance, irrigation and diversification with no objective assessment of their risk reducing effectiveness. Financial risk programs typically deal with leverage, debt structure and interest rates with no quantative analysis of financial risk exposure. Effective risk management requires that market risks, production risk and financial risks be quantified individually and then integrated in the decision making process. This challenge to quantify and integrate different types of risks has been almost totally ignored in past risk management programs.

Risk related research is given little serious consideration by extension economists or by producers. Complex optimization models based on obscure utility functions seem to have little relationship to the day to day world of producer decision making. Most risk oriented optimization models seem overly simplistic in concept and overly complex in application. Such models may provide useful insights in the basic nature of risks and risk preferences but have provided little help in developing practical, effective educational programs for producers.

An Alternative Approach to Risk Management

Risk concepts presented in this paper represent an application of basic economic theory of decision making under conditions of risk and uncertainty. However, two general characteristics distinguish the approach presented here from those used in most previous approaches to risk management. First, the process is one of analysis rather than optimization. Second, it is a parametric probability distribution based approach to decision risk analysis.

Reliance on risk analysis rather than optimization assumes that decision makers are capable of making decisions consistent with their own risk preferences but need objective assessments of relative risks and payoffs on which to base their decisions. Decision risk analysis is much more simple and thus is more easily taught and understood than is optimization under risk and uncertainty.

Parametric distribution based risk analysis facilitates consistency, simplifies risk calculation procedures, and thus contributes to overall effectiveness of educational programs. But more important, distribution based analysis allows producers to integrate probabilistic price and yield estimates into a realistic assessment of relative risks and potential profits from real world decision alternatives.

Basic Risk Concepts

Risk may be defined as the chance of a loss or otherwise unfavorable outcome (Bullock). Probability is a quantative, numerical measure of chances and thus provides a means of quantifying risk. The two basic types of risks facing agricultural producers are business risks and financial risks (Gabriel and Baker, p. 560). There are two different kinds of business risks: production risks and market risks. Production risk is the chance of an adverse outcome as a result of unfavorable yields or production costs. Market risk is the chance of an adverse outcome as a result of unfavorable market prices. Business risks represent the probability of a loss or otherwise adverse outcome resulting from unfavorable yields or production costs and/or unfavorable market prices. Business risks are determined by expected net revenues and the uncertainty of net revenues in relation to those expected levels.

Financial risk may be defined as the chance of loss or adverse outcome attributable to debt financing or leverage. Financial risks may be defined more directly as equity risk exposure (Holt and Boggess). Any given adverse net revenue outcome will represent a greater proportional loss of equity for a more highly leveraged business activity, just as any favorable outcome will be a greater proportional gain. Risk management decisions must consider both business and financial risks.

Probability Distributions of Net Revenues

Distributions of possible net revenue outcomes are joint distributions resulting from prices, costs and production levels (Hayya and Ferrara, pp. 73-74). Thus, net revenue risks are related directly to expected values of yields, prices and costs and distribution of possible outcomes about those expected values. And, distributions of yields, costs and prices are key factors in decision risk analysis.

The basic approach to decision risk analysis presented here is not dependent any specific probability distribution assumption. Any set of yield, price and cost distributions which can be specified can be combined into a joint distribution of net revenue outcomes. The resulting net revenue distribution can be integrated to estimate the probability of profit, risk of loss, or risk of any other adverse outcome.

The basic equations for estimating parameters of total revenue and total net revenue distributions for purposes of risk analysis can be expressed as follows:

1) $E(TR) = E(Y) \cdot E(P)$

2) $V(TR) = V(Y) \cdot E(P) \hat{} 2 + V(P) \cdot E(Y) \hat{} 2 + 2 \cdot COV(y,p)$

3) $E(TNR) = E(TR) - E(TC)$

4) $V(TNR) = V(TR) + V(TC) + 2 \cdot COV(tr,tc)$

where:
- E(TR) = Expected total revenue
- V(TR) = Variance total revenue
- E(TNR) = Expected total net revenue
- V(TNR) = Variance total net revenue
- V(Y) = Variance possible yields
- V(P) = Variance possible prices
- COV(y,p) = Covariance yields and prices
- COV(tr,tc) = Covariance total revenue and total costs

Symbols · and ^ mean times and power of respectively.

These basic equations may be manupulated and modified to accommodate a wide variety of economic assumptions. The complete set of equations can be used quite easily with microcomputer spreadsheets or basic programs. But, modifications can be made to simplify the relationships making computation feasible with pencil and paper or with a pocket calculator. For example, total costs per acre of per head may be assumed to be constant and prices and yields may be assumed to be uncorrelated. This eliminates the covariance term in equation 2 and makes variance of total "net" revenue equivalent to variance of total revenue thus eliminating the need for equations 4. These are not unrealistic assumptions for most situations of individual producers.

The Normal Distribution Assumption

Effective teaching of decision risk analysis may be facilitated or hindered by the choice of distribution assumptions. Distribution characteristics must be simple enough to be understood and accurate enough to be credible and useful. Consistency and familiarity are other important considerations. The teaching process is greatly simplified if the same distribution is used for yields, prices, costs, net revenue, total revenue, etc. It is easier also to teach concepts which are familiar and thus "make sense" to producers.

The approach to decision risk analysis presented here is based on an assumption of normally distributed net revenue outcomes. In general, A distribution based approach to decision risk analysis is not dependent on an assumption of normality. However, the normal distribution appears to meet the criteria of accuracy, familiarity and consistency as well or better than any alternative. Also, statistical theory for normally distributed random variables is well developed thus simplifying routine risk evaluation.

In distribution choices, it is important to recognize that observed variability of past outcomes is conceptually different from the distribution of possible future outcomes. While the past can be a guide to the future, past variability of net revenue over time may not yield accurate estimates of the risks confronting decision makers at a particular point in time (Peck, p. 410). Also, the relevant distribution for decision risk analysis is the distribution of forecast error or unpredictable variability and not total variability. Forecast error distributions may be quite different in magnitude and in first and higher order moments from distributions representing total variability. Distribution assumptions should be based on a realistic assessment of the nature of possible future outcomes at the time of decision.

The normal distribution probably is more widely used and more familiar to the general public than any other probability distribution. The triangular distribution has been chosen by some economists because it is easy to elicit "best, worst, and most likely" outcomes from producers. However, a simplified "optimistic, pessimistic, and most likely" approach to eliciting parameters of the normal distribution is equally easy (Ferrar and Hayya, 1970). The normal distribution, unlike the triangular distribution, allows for the possibility of extreme outcomes.

An optimistic outcome may be defined as an unfavorable outcome such that there is a one-in-six chance of an outcome as good or better than the optimistic level. An expected outcome may be defined as the level at which there is an equal chance of an outcome either better or worse than the expected level. A pessimistic outcome may be defined as unfavorable outcome such that there is a one-in-six chance of an outcome as bad or worse than the pessimistic level. These three outcome levels provide information needed to estimate the parameters of a normal distribution.

This approach at first may seem awkward because it asks for the outcome associated with a predefined probability rather than the probability associated with a predefined outcome. However, producers who have been taught basic probability concepts using coin and dice illustrations have had little difficulty in making the transition to optimistic, expected and pessimistic risk ratings for prices and yields.

Triangular distributions may be chosen by some because skewed distributions can be easily simulated through their use (Walker and Nelson, p. 10). However, skewed distributions can be simulated without discarding the basic normality assumptions. The difference between an expected and optimistic outcome provides an estimate of the standard deviation of the distribution of possible outcomes above the distribution mean. Likewise, the difference between an expected and pessimistic outcome provides an estimate of the distribution standard deviation below the mean or expected value. Such estimates typically are at least somewhat subjective. Thus, there is little concern regarding differences between mean, median and modal values or regarding other problems of non symetrical distributions. Any skew of price and/or yield distributions becomes less important in multi-enterprise analyses. Whole farm net revenues tend to approach a symetrical, normal distribution as the number of enterprises increase, regardless of the nature of individual price and cost distributions.

Some distributions of prices and yields may be discontinuous resulting in discontinuous revenue distributions. Price distributions for commodities covered by government loan and yield distributions for insured crops are two common examples. Derivation of net revenue distributions are more complex, but none the less possible, for these dincontinuous distributions. Application of basic statistical probability theory will yield the necessary total and net revenue distributions thus allowing decision risk analysis.

The normal distribution has an added advantage of consistency. Any linear combination of normal distributions results in another normal distribution (Morrison, p. 10). Thus, if prices and costs are assumed to be normally distributed, price minus cost will be normally distributed, as in equation 4. However, a problem arises with the product of normally distributed variables as shown in the general total revenue relationship of equation 2. If both prices and yields are normally distributed, multiplying yields times prices may not result in a normally distributed total revenue (Ferrara and Hayya, p. 24). However, even in these cases, statistical theory provides guidelines for conditions under which normal approximations may be assumed.

Anderson simulated distributions for products of normally distributed wheat, corn, soybean, stocker, and feeder cattle prices and yields. The tests for normality consistently led to rejection of hypotheses that total revenues (price times yield) were normally distributed at the 0.01 significance level. However, the simulations indicated errors of less than a 1 percent in normal distribution based probability estimates at plus or minus one standard deviation, assuming total revenue and price and yield were uncorrelated. That is, the proportions of simulated net revenue outcomes above or below mean values plus or minus one standard deviation consistently were within 1 percent of proportions expected if total revenues had been normally distributed.

These results imply little risk of an erroneous conclusion from assuming normally distributed total revenues for most single agricultural enterprise analyses. Normally distributed yields and prices in the basic total revenue relationship, equation 1, would be expected to carry through to an approximate normal distribution of total net revenue, equation 4. Any significant limitations will be associated with probability estimates for outcomes near expected values or more than 2-3 standard deviations from the mean.

The central limit theorem supports an assumption of a normal distribution for variables that result from the linear combination of a large number of independent random events (Morrison, p. 85). The central limit theorem also applies to multidistributional variables such as combined total net revenue from several enterprises. So, normality of whole farm net revenues resulting from several enterprises may require only the assumption of randomness rather than normality of costs, prices and yields.

Decision Risk Analysis Results

Risk rated prices and yields are translated into risk rated net revenues, utilizing statistical properties of normally distributed random variables. Expected, optimistic and pessimistic net revenues have precisely the same probabilistic properties as expected, optimistic and pessimistic prices and yields. A positive or negative expected value indicates whether the odds favor a profit or loss. Decision risk analysis indicates "how much" the odds favor a profit or loss as well as the potential for larger than expected profits or risks of larger than expected loss.

Financial risks estimates can be derived quite easily once the parameters of total net revenue distributions have been estimated. Risk rated returns to equity can be calculated in percentage terms and in terms of total dollars. However, the most direct measure of financial risk is the probability of an equity loss or otherwise unfavorable equity return. The return level relevant in measuring financial risk will depend on the level considered important by the decision maker.

Simultaneous consideration of production, market and financial risks allows producers to determine the type as well as total amount of risk associated with alternative decisions. Such analysis are essential to logical decision making. Decisons are almost never exclusively production, marketing or financial in nature. An approach which allows analysis of all three types of risks is necessary if producers are to manage the risk they must face in their quest for short run survival and long run profitability.

Summary of Implications for Extension Programs

Risk rating concepts (optimistic, pessimistic, and expected) are teachable with farm and ranch clientele. These concepts, and the underlying distribution based approach to decision risk analysis, have been integrated into a wide variety of decision aids for farmers and ranchers. Some risk rated programs have utilized microcomputers spreadsheets and programmable calculators (eg. Ikerd and Epplin, and K. Anderson and Ray). A whole farm risk rated management program also is available for microcomputers (K. Anderson and Ikerd).

Presentations have been made to a wide variety of producer groups utilizing various aspects and applications of risk rated management strategies. These programs have met with approval and have been highly evaluated by producer clientele (Ikerd and Anderson, 1984). Risk ratings have been integrated in enterprising planning budgets for a wide range of commodities (Ikerd, 1986). An educational package has been developed using the distribution based approach to assist farmers in evaluation of alternative risks of cash, futures and and commodity options markets (Ikerd, 1984). In addition, a complete set of extension program materials has been prepared and distributed for use by extension economist who choose to utilize the risk rated approach to decison risk analysis (Anderson and Ikerd, 1985).

The primary advantages of the approach presented here are simplicity and accuracy. Clientele, in fact, can understand the simplified concepts of optimistic, pessimistic, and expected outcomes. Thus, producers can make explicit, objective use of information that they previously discarded or used only intuitively. Producers have information concerning distributions of potential yields and prices. The risk rated approach to decision risk analysis allows them to use whatever quantity and quality of information they have for all it is worth. Thus, to the extent that they possess positive information, their decisions will be improved.

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