1 Introduction to Risk in Agriculture

Examples of Risky Decisions in Agriculture, and Their Implications

The development of agriculture in early times was partly a response to the riskiness of relying on hunting and gathering for food. Since then, farmers and others have tried to find ways to make farming itself less risky by achieving better control over the production processes. As in other areas of human concern, risk remains a seemingly inevitable feature of agriculture, as the examples below illustrate.

Example of institutional risk

A dairy farmer finds that the profitability of his herd is constrained by his milk quota. He now has the opportunity to buy additional quota, using a bank loan to finance the purchase. The farmer, however, has serious doubts about the profitability of this investment because he believes that milk quotas will be removed at some time in the future. Cancellation of quota would make the purchased quota valueless from that point in time. He also thinks it is likely that milk prices will drop significantly when the quotas go. His options, therefore, are to restrict milk output to the current quota or to invest to get the benefits from increased scale and intensity of milk production. But investing means that, if the quota was to be abolished, and prices fell, he might not be able to repay the loan.

Animal welfare example

Along with a group of other interested producers, a pig farmer is considering whether to switch to a method of production that takes more account of the welfare of the animals. In addition to her personal preferences, she believes that there is a potential premium to be earned from sale of pig meat produced in a way more in tune with good standards of animal welfare. To change to the new system, considerable investment would be needed to provide better and more spacious accommodation for the pigs. Production costs would also increase owing to the need to provide larger-size housing, straw for bedding and a wider range of types of feed. However, there is considerable uncertainty about whether the new product, pig meat produced in a more welfare-sensitive way, can be marketed successfully and whether consumers will pay the premium needed to cover the extra costs.

Conversion to organic farming example

Organic farming has become more popular in response to increased consumer demand for organic produce. In addition, in several countries, conversion grants and support schemes for organic farming have been introduced to encourage organic production. There are reasons to believe that conventional and organic farming systems respond differently to variations in weather, implying different impacts on farm income risk. For example, restrictions on pesticide and fertilizer use may give rise to different production risk in organic farming than in conventional farming. Prices for organic produce may fall as more producers switch to organic production, and smaller organic markets may mean greater price fluctuations. A farmer considering switching to organic production would need to take account of the changed exposure to risk.

Insurance example

A vegetable grower farms land close to a major river and is worried about the risk of a significant flood that would destroy her crops. Her insurance company offers flood insurance to cover the potential financial loss, but the annual premium is high because of the high risk of floods at that particular location. The grower is wondering what proportion of the risk she should insure, if any.

Flower growing example

A flower grower is concerned about energy use for glasshouse heating. His current heating system is obsolete and he is considering replacing it with a new one, either a conventional design or a low-energy system. The relative profitability of the two options depends on future energy prices. If future energy prices stay as they are or rise only moderately, the conventional system will be the most profitable choice. However, if future energy prices rise substantially, the low-energy system will be best, even though it is more expensive to install.

Potato marketing example

A potato farmer is about to harvest his crop. He has to decide whether to sell the potatoes now, at the current price, or to store them for sale later in the hope of a higher price. The first option gives him a sure return for his harvest. With the second option, however, he has to face storage costs and losses, yet the future price is uncertain and depends on the market situation later in the year. If the market is in short supply, prices will rise and he will make a good profit from storage. If supply is average, prices will not rise much and he may just break even. But an over-supplied market will mean a fall in prices, causing a significant loss from a decision to store rather than sell immediately. Yet, at the time the decision to sell or store has to be made, the farmer cannot be sure what the future supply situation will be since it will depend on yields of crops yet to be harvested, grown in other areas.

Farm purchase and financing example

A dairy farmer has sold her previous farm for urban development at a good price, leaving her with funds for re-investment. She is wondering whether to invest in stocks and bonds or to buy another dairy farm, which is the business she knows best. If she buys a new farm, she has to decide how large a unit to purchase. In order to buy a farm to run of a commercial size, she will have to borrow some of the funds needed for the investment. Since she believes that scale economies in dairy farming will become more important in the future, she has to decide how much she is prepared to borrow and on what basis. Options include a loan where the future interest rate varies with economic conditions or one where at least a part of the funds is at a fixed, but initially higher, interest rate.

Disease policy example

Foot-and-mouth disease poses serious risks to farming in many countries. Outbreaks of the disease require costly control measures, including the slaughter of all animals on infected farms and bans on the movement of animals in the vicinity. A basic policy choice is between routine vaccination or not. Routine vaccination is costly and not fully effective, so that some outbreaks could still occur. In addition, because vaccinated animals show positive for the disease in immunological tests, it is not possible to certify vaccinated stock as disease-free. However, without routine vaccination most animals would have no immunity. In the event of an outbreak, therefore, there is the potential for the disease to spread freely. In reaching a policy decision, in addition to ethical issues, policy makers evidently have to weigh the fairly certain costs and losses of vaccination against the less certain consequences of no vaccination. The latter choice would save vaccination costs and preserve access to export markets, but creates the risk that future outbreaks could be serious and costly.

The need to take account of risk in agriculture

As these examples show, risk can be important in agriculture. Indeed, risk and uncertainty are inescapable in all walks of life. Because every decision has its consequences in the future, we can seldom be absolutely sure what those consequences will be. Yet risk is not something to be too afraid of. It is often said that, in business, profit is the reward for bearing risk: no risk means no gain. The task rather is to manage risk effectively, within the capacity of the individual, business or group to withstand adverse outcomes.

Of course, farmers the world over have always understood the existence of risk and have adjusted to it in their own ways in running their farms. Yet, with a few notable exceptions, rather little practical use has been made of formal methods of risk analysis in agriculture. One reason may have been the effective elimination of at least some sources of risk provided by various government schemes to support the prices of farm products, such as the Common Agricultural Policy of the European Union (EU) and farm support programmes in the USA. The fact that prices of many agricultural products have been reasonably well assured in countries where such measures of protection have been in operation no doubt reduced the need to give a lot of attention to risk management. However, trade negotiations such as those at the World Trade Organization have led to changes in agricultural policies, with obligations on member countries to reduce levels of protection, especially via price supports. Moreover, many believe that these reforms are just first steps leading to further measures towards liberalization of international trade in farm products. The outlook, therefore, may be that many farmers will face greater exposure to competitive market forces and so will enjoy less predictable consequences than has been their experience.

A further reason for the relative neglect of risk is that the methods for the analysis of risky choice, although available for many years, are a good deal more complex than the more familiar forms of analysis under assumed certainty, such as the commonly used budgeting methods. The various methods that have been developed for analysing choices involving risk are collectively called *decision analysis*. Advances in computer software and hardware have made application of the methods of decision analysis simpler and quicker than in the past, bringing them within ready reach of farmers, farm advisers and agricultural policy analysts. It is therefore timely to examine the scope for wider application of decision analysis in agriculture.

Risk and Uncertainty

Some definitions

The terms 'risk' and 'uncertainty' can be defined in various ways. One common distinction is to suggest that risk is imperfect knowledge where the probabilities of the possible outcomes are known, and uncertainty exists when these probabilities are not known. But this is not a useful distinction, since cases where probabilities are objectively 'known' are the exception rather than the rule in decision making. Instead, in line with common usage, we define *uncertainty* as imperfect knowledge and *risk* as uncertain consequences, particularly possible exposure to unfavourable consequences. Risk is therefore not value-free, usually indicating an aversion for some of the possible consequences. To illustrate, someone might say that he or she is uncertain about what the weather will be like tomorrow – a value-free statement simply implying imperfect knowledge of the future. But the person might go on to mention that he or she is planning a picnic for the next day and there is a risk that it might rain, indicating lack of indifference as to which of the possible consequences actually eventuates.

To take a risk, then, is to expose oneself to a chance of loss or harm. For many day-to-day decisions, the risk is usually unimportant since the scope of possible loss is small or the probability of suffering that loss is judged to be low. Crossing a street carries with it the risk of death by being run over by a vehicle, yet few people would see that risk as sufficiently serious to prevent them making the crossing for quite trivial benefit, such as the pleasure of buying a newspaper or an ice cream. But, as the earlier examples show, for important business or personal decisions or for some government policy decisions, there is a good deal of uncertainty, and there are important differences between good and bad consequences. For these decisions, therefore, risk may be judged to be significant. In farming, many farm management decisions can be taken with no need to take explicit account of the risks involved. But some risky farm decisions will warrant giving more attention to the choice among the available alternatives.

Types and sources of risk in agriculture

Because agriculture is often carried out in the open air, and always entails the management of inherently variable living plants and animals, it is especially exposed to risk. *Production risks* come from the unpredictable nature of the weather and uncertainty about the performance of crops or livestock, for example, through the incidence of pests and diseases, or from many other unpredictable factors.

In addition, prices of farm inputs and outputs are seldom known for certain at the time that a farmer must make decisions about how much of which inputs to use or what and how much of various products to produce, so that *price* or *market risks* are often significant. Price risks include risks stemming from unpredictable currency exchange rates.

Governments are another source of risk for farmers. Changes in the rules that affect farm production can have far-reaching implications for profitability. For example, a change in the laws governing the disposal of animal manure may have significant impacts; so too may changes in income-tax provisions, or in the availability of various incentive payments. Horticultural producers may be badly affected by new restrictions on the use of pesticides, just as the owners of intensive pig or poultry operations may be affected by the introduction of restrictions on the use of drugs for disease prevention and treatment. Risks of these kinds may be called *institutional risks*. Institutional risks embody *political risks*, meaning the risk of unfavourable policy changes, and *sovereign risks*, meaning the risks caused by actions of foreign governments, such as a failure to honour a trade agreement. Also under this heading we might include *contractual risks*, meaning the risks inherent in the dealings between business partners and other trading organizations. For example, the unexpected breaking of agreements between participants in supply chains is an increasingly significant source of risk in modern agribusiness.

The people who operate the farm may themselves be a source of risk for the profitability and sustainability of the farm business. Major life crises, such as the death of the owner or the divorce of a couple owning a farm in partnership, may threaten the existence of the business. Prolonged illness of one of the principals may cause serious losses to production, or substantially increased costs. And carelessness by the farmer or farm workers, in handling livestock or using machinery for example, may similarly lead to significant losses or injuries. Such risks may be called *human* or *personal risks*.

The aggregate effect of production, market, institutional and personal risks comprise *business risks*. Business risks are the risks facing the firm independently of the way in which it is financed. Such risks comprise the aggregate effect of all the uncertainty influencing the profitability of the firm. Business risks affect measures of farm business performance such as the net cash flow generated or the net income earned.

In contrast to business risks, *financial risks* result from the method of financing the firm. The use of borrowed funds to provide some of the capital for the business means that a share of the operating profit must be allocated to meeting the interest charge on the debt capital before the owners of the equity capital can take their reward. Debt multiplies the business risk from the equity holders' viewpoint; an effect sometimes known as *leverage*. Moreover, the greater the proportion of debt capital to total capital, the higher the leverage, hence the greater the multiplicative factor applied to business risk. Only if the firm is 100% owner-financed is there no financial risk owing to leverage.

In addition to the financial risks associated with leverage, there are financial risks in using credit. The most significant of these are: (i) unexpected rises in interest rates on borrowed funds; (ii) the unanticipated calling-in of a loan by the lender; and (iii) the possible lack of availability of loan finance when required. Changes in the inflation rate can have positive or negative effects on both borrowers and lenders.

Impacts of risk

There are two reasons why risk in agriculture matters, as outlined in turn below.

Most people dislike risk

Most people are risk averse when faced with significantly risky incomes or wealth outcomes. A person who is risk averse will be willing to forgo some expected return for a reduction in risk, the rate of acceptable trade-off depending on how risk averse that individual is. Evidence of farmers' risk aversion is to be found in many of their actions, such as their willingness to buy certain kinds of insurance or their tendency to prefer farming systems that are more diversified than might seem best on profit grounds alone.

The existence of risk aversion means that analysis of risky choices in terms of their average or expected consequences will not always lead to the identification of the option that will be most preferred. Farmers, like most people, do not, and will not wish to, make choices based on what will pay best 'in the long haul' if that choice means exposing themselves to unacceptable chance of loss. Evidently, this aversion to risk has to be taken into account in developing and applying methods of decision analysis. We return to this matter in Chapter 5.

Downside risk

In the finance sector, downside risk is typically taken to mean an estimate of the potential that a security might decline in price if market conditions turn bad. Here we use the term rather differently and more generally to mean the risk that the payoff from a risky choice will be reduced if conditions are not as assumed. Downside risk, in our terms, can arise from two different causes that, in some situations, can operate in unison to magnify the risk that the consequences of some risky choice will be less than foreseen at the outset.

First, downside risk can occur when decisions are made under assumed certainty, based on some 'norm' or 'best estimate' of the consequences. The imprecision of such terms makes it hard to be sure what is implied, but evidently some single-valued measure of central tendency of some unspecified probability distribution of the payoff is implied – perhaps the mode (most likely) outcome. The risk here arises if the distribution of outcomes is negatively skewed so that the mode is above the mean (see Chapter 3, this volume).[1] Yet it is the latter that is the measure of central tendency that is more relevant in risky decision making. For a negatively skewed distribution of payoffs, there is a greater probability that the outcome will fall below the mode than above it, which is what we mean by downside risk.

Second, downside risk may also arise when a risky outcome depends on non-linear interactions between a number of uncertain quantities. The yield of a crop provides an obvious example. Yields depend on a large number of uncertainties, such as rainfall and temperature in each stage of the growing season. Large deviations of these uncertain variables in either direction from their expected values often have adverse effects – too much rain may be as bad as too little. While some smaller deviations may have beneficial effects, the 'law of diminishing returns' usually means that losses associated with adverse deviations from the mean level of, say, rainfall, are greater than the gains associated with favourable deviations of a similar magnitude. A natural definition of a 'normal' season is one in which all variables take values close to their expected values. The probability of a season defined in this way is necessarily small, however, and the non-linear interactions of the variables imply a high probability of yields less than those obtained in such a 'normal' season. Thus, the use of this notion of a normal year as the basis for analysis creates a situation in which downside risk is dominant. By contrast, downside risk is accommodated by the use of the mean of the series of observed yields (suitably adjusted for any trend), or of a well-considered estimate of the mean, as the basis for analysis.

Note that treating input variables as certain when they are not often leads to downside risk whether the distributions of the input variables are skewed or not. However, the downside risk is more severe when both causes are present. Assuming input variables take their modal or 'normal' values will commonly lead to greater downside risk than assuming they take their mean values.

We can illustrate the impact of these causes of downside risk with a simplified example relating to production of a crop the yield of which is assumed to be a quadratic function of growing-season rainfall:

$$y = 0.4\,x - 0.00075\,x^2 \qquad (1.1)$$

where y is yield in tonnes per hectare and x is growing-season rainfall in millimetres. For this example, we assume that rainfall in the growing season is uncertain and can be represented by a relative frequency histogram based on historical information with a minimum of 100 mm, a maximum of 300 mm and a most likely value of 225 mm. The specified distribution has a mean value of 209 mm. Both the rainfall distribution and the crop yield function are illustrated in Fig. 1.1.

If we evaluate the crop yield on the assumption that the coming growing season will be 'typical', implying rainfall of 225 mm previously defined as 'most likely', the calculated yield is 52.0 t/ha. However, if we use instead the expected value (mean) of growing-season rainfall of 209 mm, the calculated yield is reduced to 50.8 t/ha. On the other hand, if we take full account of the whole distribution of rainfall, the expected yield[2] is 49.5 t/ha. The latter is the yield that a grower could 'expect' to get if he or she had no prior knowledge of what rainfall would be beyond the information represented in the specified relative frequency distribution. Such a state of knowledge would be typical of a grower at planting time. Thus, as shown in Table 1.1, we have two yield estimates under the unrealistic assumption of certain foreknowledge of rainfall, and one more satisfactory estimate obtained recognizing the entailed risk. The difference

[1] Assuming that the outcome is something desirable such that more is preferred to less, not something that is disliked with less being preferred to more.

[2] Calculated using stochastic simulation, outlined in Chapter 6, this volume.

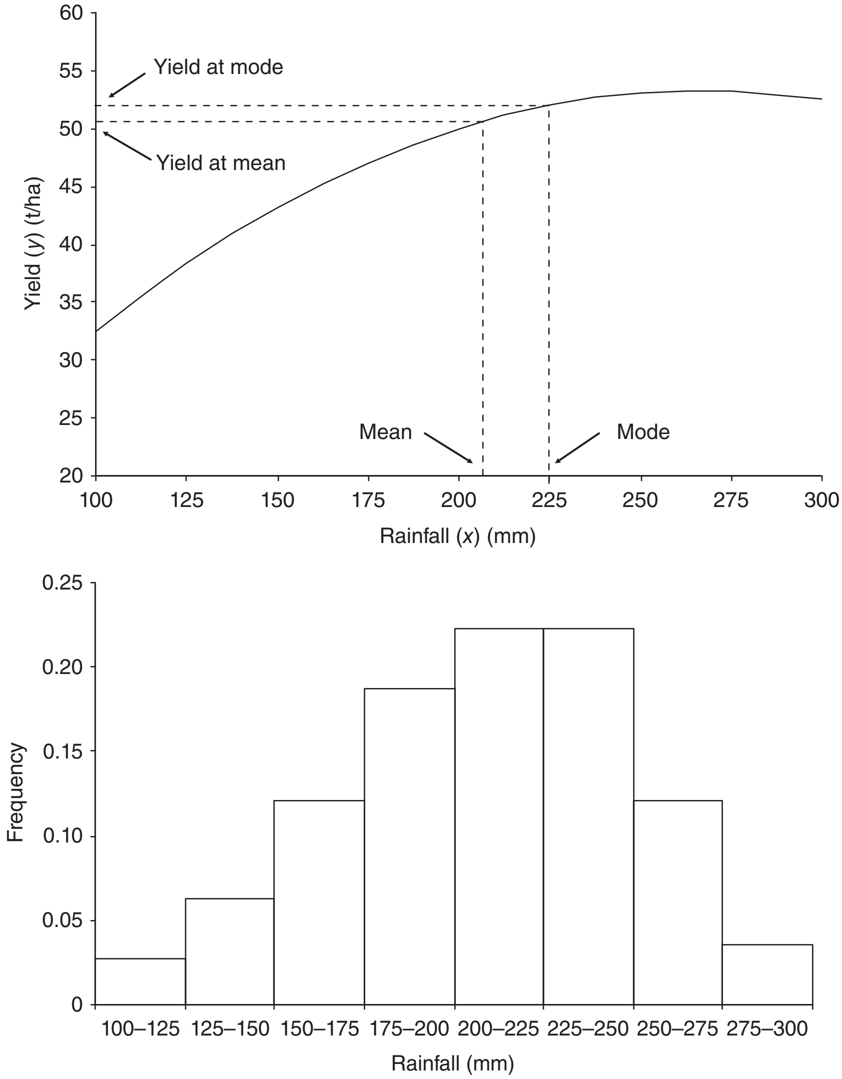

Fig. 1.1. Illustration of downside risk showing the assumed crop yield response to rainfall and the relative frequency distribution for growing-season rainfall.

Table 1.1. Effect of assumptions about rainfall on expected crop yield.

Assumption about rainfall	Calculated expected yield (t/ha)
Assumed certainty: Mode of 225 mm	52.0
Assumed certainty: Mean of 209 mm	50.8
Accounting for risk via actual distribution	49.5

between the third, more realistic yield estimate and the other two may be regarded as downside risk. Under the perhaps common assumption that the growing season rainfall will be 'normal' (i.e. the modal value) downside risk amounts to an over-estimate of expected yield of 52.0 – 49.5 = 2.5 t/ha. Even if the analysis under assumed certainty is based on the mean rainfall, the downside risk is still 50.8 – 49.5 = 1.3 t/ha.

In a similar vein, other uncertain factors besides rainfall will also generally not operate at their 'normal' values. There will be impacts of pests, diseases, frosts, strong winds, wildfires, foraging by uninvited animals, and so on, to be considered. The multiplicity of effects from many causes will tend to magnify downside risk to an extent that may make a decision-analytic assessment of the riskiness involved important and informative.

Some readers may believe that the difference in yield between assumed certainty and a risk analysis comes about mainly because of the somewhat skewed nature of the rainfall distribution. This is not the case since, for the data used, there is no difference in the calculated expected yield derived from a risk analysis whether that analysis is done using the given empirical distribution of rainfall or using a normal distribution with the same mean and standard deviation. However, in other cases, as noted above, skewness may contribute to downside risk.

Put most simply, downside risk occurs because nature tends to be unkind to human endeavours. In other words, bad outcomes are not fully offset by good ones. For example, catastrophes such as terrorist attacks or major natural disasters happen all too often, killing large numbers of people. Yet it is impossible to imagine any equivalently good outcomes that could compensate for the losses suffered. Were such an event to occur it would undoubtedly be called a miracle. When planning under uncertainty it is important to think about what can go wrong and what can go right, recognizing that the negatives typically outweigh the positives. Risk analysis is needed to account for this effect.

Who Needs to Think about Risk in Agriculture?

People and organizations who need to concern themselves with risk in agriculture include:

1. farmers;
2. farm advisers;
3. commercial firms selling to or buying from farmers;
4. agricultural research workers; and
5. policy makers and planners.

The need for farmers to plan for the risks they face hardly needs emphasis. The welfare of the farm family and the survival of the farm business may depend on how well farming risks are managed. In hard times, farm bankruptcy may occur, and many more farms survive when things go wrong only by 'belt tightening' and by such measures as finding off-farm employment. The ambition of many farmers to hand the farm on in a thriving condition to the next generation of the family can be frustrated if risk management is neglected.

Farm advisers also need to recognize that risk and risk aversion influence farmers' management decisions. Advice that overlooks the risks involved in changing from an existing production system to one that is supposedly 'superior' is bad, even negligent, advice. Advisers need to understand that the adoption of an untested 'improved' technology may entail a high degree of risk for the farmer, especially if the adoption of the technology requires a substantial capital investment. The perceived risk may be high because the farmer has had no first-hand experience of the new method. So, if the technology is 'lumpy', in the sense that it cannot be tried out on a pilot scale, there will be an 'adoption lag' until the farmer has accumulated sufficient evidence to make the perceived risk acceptable. Advisers may be able to speed the adoption process by measures that reduce the degree of risk perceived by the farmers, such as by supplying relevant technical and economic information, arranging field demonstrations, organizing visits to other farms where the technology is in use, and so on. More generally, it may be possible to present information and advice in ways that better portray the risks involved and that permit a farmer to decide more easily which choices best suit his or her particular circumstances and risk-bearing capacity.

Suppliers of inputs to farmers face similar challenges to those encountered by advisers. They need to recognize that the purchase of a new product may be a risky decision for farmers, especially where items involving a substantial investment are concerned. Suppliers can use the same sorts of methods as just mentioned to reduce the risks perceived by their intended clients. Leasing arrangements may be better than direct purchase for risk-averse farmer clients, so that those suppliers who can offer this option may have more success. Similarly, agricultural traders who buy from farmers may do well to consider the motivation of farmers to reduce price risks. Thus, some farmers will be willing to accept a lower price for their output if the buyer is prepared to offer a forward contract at an assured price. Both buyer and seller can benefit from such an arrangement.

Agricultural research workers, especially those working on the development of improved farming methods, may need to give more thought to risk aspects. For example, too often the results of trials are reported in terms of (differences between) treatment averages, with inadequate representation of the dispersion of results about the reported averages. Basing conclusions on 'statistically significant' differences in means between treatments fails to tell the whole story if there are differences in dispersion of outcomes. The variability of results across plots within a single trial is sometimes indicated, but seldom is information provided on the variability across different experimental sites or over a number of years. Yet the latter information may be vital for a proper assessment of relevant risks. Agricultural research that recognizes risk may entail more than simply better reporting of trial results. Thinking about farmers' production constraints and opportunities in a world in which risk is recognized will lead researchers to identify different research problems, or to address the problems they do identify in different, more complete ways. For example, both animal and crop breeders tend to base selection on performance under well-controlled conditions, such as good nutrition. This practice may mean the loss of genetic capacity in the animals or plants to thrive in less favourable conditions, so increasing the losses when things go wrong and making production more risky, for example, cereal varieties that lodge if the growing season is wet.

Agricultural policy makers and planners also need to account for risk and farmers' responses to it. Estimates of supply response obtained from models that ignore risk-averse behaviour by farmers can be significantly biased. In other words, models that include risk can provide better predictions of farmers' behaviour than those that do not. Similarly, policy making and planning are themselves risky activities, so that some of the methods of risk analysis discussed in the following chapters are relevant, although in a rather different context, as discussed in Chapter 13.

Policy makers and planners need to consider farmers' concerns and risk-averse behaviour when setting policies and programmes directly affecting (or causing) farming risk. For example, some time back, extensive beef producers in northern parts of Australia had a thriving market for live cattle in Indonesia. When a TV programme revealed significant cruelty in an Indonesian abattoir, the Australian authorities promptly banned the export trade. However justified that decision may have been, it caused massive problems for cattle producers in remote northern Australia, many of whom were simply unable to sell their cattle. Apart from significant losses for these producers, Indonesian consumers faced beef shortages, while drought and over-grazing on Australian cattle farms may well have led to many animals starving to death. It seems likely that the decision makers (DMs) had not foreseen the serious implication of their hasty intervention. Evidently, policy makers need to be aware of the consequences for farmers and others of risks created by their own unpredictable behaviour.

Risk Management and Decision Analysis

Many descriptions of the process of risk management view risk as rather like a disease that has to be treated. For example, the International Standard on Risk Management (ISO, 2009) has at its core the identification, analysis, evaluation and treatment of risks. While it can be helpful to look at risk in this way, this is not the approach we choose to follow in this book. Instead of treating risk management as something that is separate from general management of an organization, we see a need to account for risk as an integral part of all management decision making. We take this view because just about every decision has its consequences in the future, and we can never be certain about what the future may bring. So most if not all management decisions create some risk exposure. Making risk management a separate process ignores this reality. Moreover, economics teaches that profit is the reward for risk taking – no risk means no gain. So what is needed is a process to balance risk against possible rewards. Separating out the treatment of risk may obscure the need to get the balance right.

Obviously, some decisions are more risky than others, and those for which the range of possible consequences is narrow, with little or no chance of a really bad result, can be handled easily with a bit of common sense. But there are also other decisions for which the range of possible consequence is wide, perhaps with a non-trivial chance of bad outcomes. For these decisions much more careful consideration will certainly be warranted. However, dealing with such risky choice is not easy – there may be many options to choose between and the consequences of each may depend on many uncertain factors. Procedures aimed at getting to grips with just such important but difficult risky choices fall under the general heading of *decision analysis* and it is these procedures that form the main part of this book.

Decision analysis may be defined as the philosophy, theory, methods and practices necessary to systematically address important risky decisions. In this book we focus on an approach to decision analysis founded on the theory of *subjective expected utility*, as described in the next chapter. Decision analysis includes methods and tools for identifying, representing and assessing important aspects of a risky decision, leading to a recommended course of action consistent with careful consideration of the possible consequences of the alternative choices, the associated probabilities of those consequences, and the relative preference for possible outcomes. In other words, it is a prescriptive theory of choice.

When Formal Decision Analysis Is Needed

Formal analysis of risky choice in agriculture obviously has costs, including the costs of the time to do the required thinking and figuring. Not all decisions will warrant this input of effort. There are at least two cases where formal analysis may be thought worthwhile.

The first is for repeated risky decisions for which a sensible strategy might be devised that could be applied time and again. The benefit from better individual decisions may be small, but the accumulated benefit over many decisions may justify the initial and continuing investment of time and effort in analysis. An example is the development of a strategy for the treatment of mastitis in dairy cows. This is a commonly occurring disease that, if untreated, can damage the animal and can lead to penalties for the farmer when milk delivered to the dairy factory is found to contain high bacterial loads. Treatment with antibiotic has costs, including the need to divert milk from cows being treated from that being sold. Because the disease may occur repeatedly, and on-farm tests for the presence of the disease are not wholly reliable, the design and implementation of a good strategy for managing mastitis makes sense.

The case of decision analysis for many repeated decisions may be extended to advisory situations where an analyst may be justified in putting considerable effort into devising good risk-management procedures for some aspect of farming that could be adopted by many farmers. The choice of a planting strategy for potatoes in frost-prone areas might be such an example. It may be known that yields are generally improved by early planting, but early-planted crops are obviously more vulnerable to late spring frosts. The adviser may be able to use weather records in a decision analysis to develop recommendations to guide local potato growers.

The second case for formal analysis arises when a decision is very important, in the sense that there is a considerable gap between the best and the worst outcomes, one big enough to have a significant impact on wealth. A case in point is a major investment decision. A farmer may be deciding whether it would be worthwhile to invest in the purchase of another farm, in order to expand the size of the business with the goal of attaining long-run viability in the face of an expected cost-price squeeze. Yet the investment may require considerable borrowing that could lead to bankruptcy if things go wrong.

The fact that a decision or a set of decisions is sufficiently important to justify efforts to reach a better choice is not the only consideration in deciding whether to undertake a formal analysis. Many real choices in agriculture are complex. Some common characteristics of complex decision problems are:

1. The available information about the problem is incomplete.
2. The problem involves multiple and conflicting objectives.
3. More than one person may be involved in the choice or may be affected by the consequences.
4. Several complex decision problems may be linked.
5. The environment in which the decision problems arise may be dynamic and turbulent.
6. The resolution of the problem may involve costly commitments that may be wholly or largely irreversible.

The psychological response of people to such complexity varies and may be more or less rational. Some simply defer choice, even when to do so is to court disaster. For example, in hard financial times when debt servicing is becoming a problem, it has been observed that some farmers may cut off communication with their bankers at the very time when they should be discussing with them how to resolve the emerging crisis. Other more or less rational responses include:

1. simplifying the complexity by searching for a course of action that is ‘good enough’, rather than ‘best’ (an inevitable procedure in all decisions, though the question of what opportunities have been forgone may or may not get considered);
2. avoiding uncertainty or taking steps to reduce it (perhaps rationally or perhaps at considerable cost);
3. concentrating on incremental measures rather than on those involving fundamental changes (perhaps thereby closing off risky but potentially rewarding options); and

4. seeking to reduce conflict of interest or perceptual differences through discussion among concerned people (often wisely, but maybe simply to defer a hard decision by 'forming a committee' or seeking to shift the burden of choice to the shoulders of others).

The fundamental question in considering the role of formal methods of decision analysis is whether, in a particular case, the need to sweep aside much of the complexity of the real decision problem will leave a representation of the problem that is:

1. sufficiently simple to be capable of systematic analysis, yet
2. sufficiently like the real situation that an analysis will aid choice.

Obviously, it is our contention that the answer to these questions will be in the affirmative sufficiently often to make it worthwhile for agriculturists and others to familiarize themselves with the formal methods of decision analysis set out in the following chapters. Whether we are right will be determined by the reactions of agricultural DMs to these ideas.

Outline and General Approach of the Book

In the next chapter, the basic approach to the analysis of risky choice is described. The central idea underlying the methods described is to break any risky decision down into separate assessments of:

1. the nature of the uncertainty affecting the outcomes of alternative actions, and hence the riskiness of the possible consequences of those actions; and
2. the preferences of the DM for the various consequences that might arise from his or her choice.

Having dissected the decision problem in this way, the two sets of judgements are then integrated in some suitable analytical framework to work out what choice would be best.

The measurement of uncertainty using subjective probabilities is the topic of Chapter 3, and ways of making better probability judgements are discussed in Chapter 4. The assessment of preferences for consequences, and hence of risk attitudes, is introduced in Chapter 5. In this chapter we also consider options when the elicitation of an individual's utility function proves too difficult. Methods of integrating beliefs in the form of probabilities and preferences expressed as utilities to reach a choice are described in Chapter 6.

Most of the rest of the book is devoted to an elaboration of these ideas. Chapter 7 deals with situations where, for whatever reason, the risk attitude of the DM cannot be accurately assessed. Chapter 8 deals with the state-contingent approach to risky choice while Chapter 9 describes methods of whole-farm planning accounting for risk, based mainly on extensions of the familiar 'programming' approach to farm planning. In Chapter 10, the methods of preference assessment introduced in Chapter 5 are extended to cases where consequences have more than one attribute that must be taken into account. Time is an important dimension to many risky farm decision problems; methods of analysis that give explicit consideration to the time dimension are introduced in Chapter 11. Some of the strategies that farmers use, or might consider using, to deal with risk are described and analysed in Chapter 12, while aspects of agricultural risk affecting policy making and planning are the topic of the final chapter, Chapter 13. In the Appendix the sources of the main special-purpose software used in the book are given.

Throughout, the aim is to make the explanations as simple as possible to appeal to a wide cross-section of readers. Often, the language of mathematics is used as the most convenient way of expressing some concept in an efficient and unambiguous way. However, for those not comfortable with the mathematical approach, other ways of explaining the same ideas have been provided, usually via a worked if simplified example. Although the use of mainly very simple examples may give the impression that decision analysis can only be applied to simple problems, this is certainly not so. The methods illustrated can also be applied to realistic decisions, but at the cost of extra complexity that would cloud rather than clarify the exposition of the underlying concepts.

Similarly, it is difficult in a text of this kind to avoid being overly prescriptive in describing the methods that can be applied. It would make the book too long and dull to discuss the pros and cons of every aspect of the methods described. Yet, as a study of the relevant literature will show, there are often 'more ways than one of skinning a cat' in decision analysis. Methods other than those described here may better suit particular situations, and practitioners should not be afraid to try out alternative approaches or to develop new ones to suit particular circumstances and needs.

An analogy can be drawn between the way a particular decision problem is conceived and analysed, and the way a landscape artist sees and represents a particular view. A good painting is not necessarily a close representation of the reality; rather it is a representation that best helps a viewer of the painting to come to a better appreciation of the scene depicted. Similarly, the best analysis of some decision problem is one that truly helps the DM to make a good choice. Such analysis generally will not be a close representation of all the detail and complexity of the real situation. Indeed, too much detail in the analysis may obscure rather than clarify the choice for the DM.

There are many constraints on what is possible to do in decision analysis. Lack of time, information, access to computer facilities and software, and limited access to the DM are just some of the factors that may limit the applicability of the methods described here. In these circumstances, novice analysts may become discouraged. They should not be. Decision analysis is the art of the possible! It is plausible to presume that an analysis that has elements of the approach is likely to be better than one that does not. To pretend that risk does not exist when it obviously does, just because accounting for risk is more difficult, is mistaken, even dishonest. The truth is that risk, along with death, is one of the few certainties of the human condition. So what is at stake is not the need to recognize risk – it is the question of how the risk is to be accounted for in reaching a decision. This question is pursued from several analytical standpoints in the subsequent chapters.

Selected Additional Reading

The approach we follow in this book, which departs from earlier traditions such as established by Knight (1933), was first popularized in US business schools such as at Harvard University (e.g. Raiffa, 1968; Schlaifer, 1969). Subsequently, a vast literature on decision analysis has evolved dealing with both the general approach and the applications to specific fields or topics. Examples include Clemen (1996) and McNeil *et al*. (2005), while Meyer (2003) provides an overview of the economics of risk.

Significant early works dealing with application to agriculture include Halter and Dean (1971), Dillon (1971), Anderson *et al*. (1977), Barry (1984) and Huirne *et al*. (1997). More recent texts relating to agriculture include Harwood *et al*. (1999), OECD (2009) and Moss (2010). Just (2003), Chavas *et al*. (2010) and Hardaker and Lien (2010) are useful expositions of the future opportunities and challenges for risk research in agriculture.

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